

TABLE 1
Completed SITE Demonstration Program Projects as of December 1996

Developer/ Technology	Demonstration Location/ Demonstration Date	Technology Contact	EPA Project Manager	Applicable Media	Applicable Waste	
					Inorganic	Organic
Accutech Remedial Systems, Inc., Keyport, NJ (005)* Pneumatic Fracturing Extraction SM and Catalytic Oxidation	New Jersey Environmental Cleanup Responsibility Act site in Hillsborough, NJ/ July - August 1992	John Liskowitz 908-739-6444	Not Available	Soil, Rock, Groundwater	Not Applicable	Halogenated and Nonhalogenated VOCs and SVOCs
American Combustion, Inc., Norcross, GA (001) PYRETRON® Thermal Destruction	EPA's Incineration Research facility in Jefferson, AR using soil from Stringfellow Acid Pit Superfund site in Glen Avon, CA/ November 1987 - January 1988	Gregory Gitman 770-564-4180	Laurel Staley 513-569-7863	Liquids, Solids, Sludges	Not Applicable	Nonspecific Organics
Babcock & Wilcox Co.,** Lynchburg, VA (006)/(E02) Cyclone Furnace	Developer's facility in Alliance, OH/November 1991	Evans Reynolds 804-522-6000	Laurel Staley 513-569-7863	Solids, Soil, Sludge	Nonspecific, Low-Level Radionuclides, Heavy Metals	Nonspecific Organics
Bergmann, A Division of Linatex, Inc., Gallatin, TN (007) Soil and Sediment Washing	Toronto, Ontario, Canada and Saginaw Bay Confined Disposal Facility in Saginaw, MI/ April 1992 and May 1992	George Jones 615-230-2217	Jack Hubbard 513-569-7507	Soil, Sediment	Heavy Metals, Radionuclides	PCBs, Nonspecific Organics
Berkeley Environmental Restoration Center, Berkeley, CA (005) In Situ Steam Enhanced Extraction Process	Lawrence Livermore National Laboratory in Altamont Hills, CA/December 1993	Kent Udell 510-642-2928 Steve Collins 510-643-1300	Paul dePercin 513-569-7797	Soil, Groundwater	Not Applicable	VOCs and SVOCs, Hydrocarbons, Solvents
Billings and Associates, Inc., Albuquerque, NM (007) Subsurface Volatilization and Ventilation System (SVVS®)	Site in Buchanan, MI/ March 1993 - May 1994	Gale Billings 505-345-1116 Don Brenneman 713-676-5324	Paul dePercin 513-569-7797	Soil, Sludge, Groundwater	Not Applicable	BTEX, Hydrocarbons
BioGenesis Enterprises, Inc., Springfield, VA (005) BioGenesis SM Soil and Sediment Washing Process	Refinery site in Minnesota/ November 1992	Charles Wilde 703-913-9700	Annette Gatchett 513-569-7697	Soil, Sediment, Sludge	Nonspecific Inorganics	Volatile and Nonvolatile Hydrocarbons, PCBs, Nonspecific Organics
Bio-Rem, Inc., Butler, IN (006) Augmented In Situ Subsurface Bioremediation Process	Williams AFB in Phoenix, AZ/ May 1992 - June 1993	David Mann 219-868-5823 800-428-4626	Teri Richardson 513-569-7949	Soil, Water	Not Applicable	Halogenated and Nonhalogenated Hydrocarbons

* Solicitation Number

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BioTrol® , Eden Prairie, MN (003) Biological Aqueous Treatment System	MacGillis and Gibbs Superfund site in New Brighton, MN/ July - September 1989	Durell Dobbins 612-942-8032	Not Available	Liquid Waste, Groundwater	Not Applicable	Chlorinated and Nonchlorinated Hydrocarbons, Pesticides
BioTrol® , Eden Prairie, MN (003) Soil Washing System	MacGillis and Gibbs Superfund site in New Brighton, MN/ September - October 1989	Durell Dobbins 612-942-8032	Not Available	Soil	Nonspecific Metals	High Molecular Weight Organics, PAHs, PCP, PCBs, Pesticides
Brice Environmental Services Corporation , Fairbanks, AK (006) Soil Washing Process	Alaskan Battery Enterprises Superfund site in Fairbanks, AK/September 1992	Craig Jones 907-452-2512	Not Available	Soil	Radioactive and Heavy Metals	Hydrocarbons
Calgon Carbon Oxidation Technologies (formerly Vulcan Peroxidation Systems, Inc.) , Pittsburgh, PA (006) perox-pure™ Chemical Oxidation Technology	Lawrence Livermore National Laboratory in Altamont Hills, CA/September 1992	Bertrand Dussert 412-787-6681	Norma Lewis 513-569-7665	Groundwater, Wastewater	Not Applicable	Fuel Hydrocarbons, Chlorinated Solvents, PCBs, Phenolics, Pesticides
CF Systems Corporation , Arvada, CO (002) Liquified Gas Solvent Extraction (LG-SX) Technology	New Bedford Harbor Superfund site in New Bedford, MA/ September 1988	L.V. Benningfield 303-420-1550	Mark Meckes 513-569-7348	Soil, Sludge, Sediment, Wastewater	Not Applicable	VOCs, SVOCs, PAHs, PCBs, Dioxins, PCP
Chemfix Technologies, Inc. , Metairie, LA (002) Solidification and Stabilization	Portable Equipment Salvage Company site in Clackamas, OR/March 1989	David Donaldson 504-831-3600	Edwin Barth 513-569-7669	Soil, Sludge, Solids	Heavy Metals, Low- Level Nuclear Waste	Not Applicable
COGNIS, Inc. ,** (009)/(E05) TERRAMET® Soil Remediation System	Twin Cities Army Ammunition Plant in New Brighton, MN/ August 1994	Not Available	Michael Royer 908-321-6633	Soil, Sludge, Sediment	Lead, Heavy Metals	Not Applicable
Commodore Environmental Services, Inc. , Columbus, OH (010) Solvated Electron Remediation System	Construction Battalion Supply Center in Port Hueneme, CA/ September 1996	Neil Drobny 614-297-0365	Paul dePercin 513-569-7797	Soils, Sludges, Sediments, Oils, Hand Tools, Personal Protective Clothing	Not Applicable	PCBs, Pesticides, Halogenated Compounds

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Dehydro-Tech Corporation , Somerville, NJ (004) Carver-Greenfield Process® for Solvent Extraction of Wet, Oily Wastes	EPA's Research Facility in Edison, NJ using wastes from the PAB Oil site in Abbeville, LA/August 1991	Theodore Trowbridge 908-904-1606	Laurel Staley 513-569-7863	Soil, Sludge, Sediment	Not Applicable	PCBs, Dioxins, PAHs, Hydrocarbon-Soluble Organics
E.I. DuPont de Nemours and Company, and Oberlin Filter Co. , Wilmington, DE (003) Membrane Microfiltration	Palmerton Zinc Superfund site in Palmerton, PA/ April - May 1990	Ernest Mayer 302-774-2277	John Martin 513-569-7758	Groundwater, Leachate, Wastewater, Electroplating Rinsewaters	Heavy Metals, Cyanide, Uranium	Organic Particulates, Volatile Organics, Oily Wastes
Dynaphore, Inc. , Richmond, VA (006) FORAGER® Sponge	National Lead Industry site in Pedricktown, NJ/April 1994	Norman Rainer 804-288-7109	Not Available	Industrial Discharge, Municipal Sewage, Process Streams, Acid Mine Drainage	Metals	Not Applicable
ECOVA Corporation , Boulder, CO (006) Bioslurry Reactor	EPA's Test and Evaluation Facility in Cincinnati, OH/ May - September 1991	William Mahaffey 303-670-2875 303-443-3282	Ronald Lewis 513-569-7856	Soil, Sludge, Sediment	Not Applicable	Creosote and Petroleum Wastes
ELI Eco Logic International Inc. , Rockwood, Ontario, Canada (006) Gas-Phase Chemical Reduction Process	Middleground Landfill in Bay City, MI/ October - November 1992	Jim Nash 519-856-9591	Gordon Evans 513-569-7684	Soil, Sludge, Liquids	Not Applicable	PCBs, PAHs, Chlorinated Dioxins and Dibenzofurans, Chlorinated Solvents and Chlorophenols
ELI Eco Logic International Inc. , Rockwood, Ontario, Canada (006) Thermal Desorption Unit	Middleground Landfill in Bay City, MI/ October - November 1992	Jim Nash 519-856-9591	Gordon Evans 513-569-7684	Soil, Sludge, Liquids	Not Applicable	PCBs, PAHs, Chlorinated Dioxins and Dibenzofurans, Chlorinated Solvents and Chlorophenols
EnviroMetal Technologies Inc. , Guelph, Ontario, Canada (008) In Situ and Ex Situ Metal-Enhanced Abiotic Degradation of Dissolved Halogenated Organic Compounds in Groundwater (Two Demonstrations)	Industrial facility in New Jersey and industrial facility in New York/November 1994 - February 1995 and May - December 1995	Larry Kwicinski 519-824-0432	Chien Chen 908-906-6985	Groundwater	Not Applicable	Halogenated Organic Compounds

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EPOC Water, Inc., Fresno, CA (004) Precipitation, Microfiltration, and Sludge Dewatering	Iron Mountain Superfund site in Redding, CA/May - June 1992	Rodney Squires 209-291-8144	Jack Hubbard 513-569-7507	Sludge, Wastewater, Leachable Soil	Heavy Metals	Nonspecific Organics
Filter Flow Technology, Inc., League City, TX (006) Colloid Polishing Filter Method®	DOE's Rocky Flats Plant in Denver, CO/September 1993	Tod Johnson 281-332-3438	Annette Gatchett 513-569-7697	Groundwater, Industrial Wastewater	Heavy Metals, Nontritium Radionuclides	Not Applicable
Funderburk & Associates (formerly HAZCON, Inc.), Apollo Beach, FL (001) Dechlorination and Immobilization	Former oil processing plant in Douglassville, PA/October 1987	Ray Funderburk 800-723-8847	Paul dePercin 513-569-7797	Soil, Sludge, Sediment	Heavy Metals	Nonspecific Chlorinated Organics
General Atomics, San Diego, CA (001) Circulating Bed Combustor	Developer's facility in San Diego, CA using waste from the McColl Superfund site in Fullerton, CA/March 1989	Jeffrey Broido 619-455-4495	Douglas Grosse 513-569-7844	Soil, Sludge, Slurry, Liquids	Metals, Cyanides, Nonspecific Inorganics	Halogenated and Nonhalogenated Organic Compounds, PCBs
General Environmental Corporation (formerly Hydrologics, Inc.), Denver, CO (008) CURE®-Electrocoagulation Wastewater Treatment System	DOE's Rocky Flats Plant in Denver, CO/ August - September 1995	Carl Dalrymple 303-889-5949 Dan Eide 561-575-3500	Steven Rock 513-569-7149	Water	Metals and Radionuclides	Not Applicable
Geo-Con, Inc., Monroeville, PA (001) In Situ Solidification and Stabilization Process (Two Demonstrations)	General Electric Service Shop site in Hialeah, FL/ April 1988	Linda Ward Robert Hayden 412-856-7700	Not Available	Soil, Sediment, Sludge	Nonspecific Inorganics	PCBs, PCP, Other Nonspecific Organics
Geosafe Corporation, Richland, WA (002) In Situ Vitrification	Parsons Chemical site in Grand Ledge, MI/March - April 1994	James Hansen Matthew Haass 509-375-0710	Teri Richardson 513-569-7949	Soil, Sludge, Sediments	Nonspecific Inorganics	Nonspecific Organics
GIS\Solutions, Inc., Concord, CA (007) GIS\Key™ Environmental Data Management System	San Francisco, CA and Washington, DC/ August 1993 (CA) and December 1993 (DC)	John Saguto 415-827-5400	Richard Eilers 513-569-7809	Not Applicable	Not Applicable	Not Applicable

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GRACE Bioremediation Technologies, Mississauga, Ontario, Canada (008) DARAMEND™ Bioremediation Technology	Domtar Wood Preserving facility in Trenton, Ontario, Canada/ Fall 1993 - September 1994	Alan Seech Paul Bucens 905-272-7480	Teri Richardson 513-569-7949	Soil, Sediment, Sludge	Lead, Manganese, Zinc	PAHs, PCP, Total Petroleum Hydrocarbons
Gruppo Italimpresse (developed by Shirco Infrared Systems, Inc.), Rome, Italy (001) Infrared Thermal Destruction (Two Demonstrations)	Peak Oil Superfund site in Brandon, FL and Rose Township-Demod Road Superfund site in Oakland County, MI/ August 1987 (FL) and November 1987 (MI)	Not Available	Laurel Staley 513-569-7863	Soil, Sediment	Not Applicable	Nonspecific Organics
High Voltage Environmental Applications, Inc. (formerly Electron Beam Research Facility, Florida International University, and University of Miami),** Miami, FL (008)/(E03) High-Energy Electron Irradiation	DOE's Savannah River site in Aiken, SC/ September - November 1994	William Cooper 305-593-5330	Franklin Alvarez 513-569-7631	Liquid, Sludge	Not Applicable	Most Organics
Horsehead Resource Development Co., Inc., Palmerton, PA (004) Flame Reactor	Developer's facility in Monaca, PA using waste from National Smelting and Refining Company Superfund site in Atlanta, GA/ March 1991	Regis Zagrocki 610-826-8818	Marta K. Richards 513-569-7692	Soil, Sludge, Industrial Solid Residues	Heavy Metals	Not Applicable
Hrubetz Environmental Services, Inc., Dallas, TX (007) HRUBOUT® Process	Kelly Air Force Base in San Antonio, TX/ January - February 1993	Michael Hrubetz Barbara Hrubetz 214-363-7833	Gordon Evans 513-569-7684	Soil	Not Applicable	Halogenated or Nonhalogenated VOCs and SVOCs
Hughes Environmental Systems, Inc., (005) Steam Enhanced Recovery Process	Fuel spill site in Huntington Beach, CA/ August 1991 - September 1993	Not Available	Paul dePercin 513-569-7797	Soil, Groundwater	Not Applicable	VOCs, SVOCs, Hydrocarbons, Solvents

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IIT Research Institute/Brown and Root Environmental, Chicago, IL (007) Radio Frequency Heating	Kelly Air Force Base in San Antonio, TX/August 1993	Harsh Dev 312-567-4257 Captain Jeff Stinson 904-283-6254 Clifton Blanchard 423-483-9900	Laurel Staley 513-569-7863	Soil	Not Applicable	Petroleum Hydrocarbons, VOCs, SVOCs, Pesticides
Ionics/Resources Conservation Company, Bellevue, WA (001) B.E.S.T. Solvent Extraction Technology	Grand Calumet River site in Gary, IN/July 1992	William Heins 206-828-2400	Mark Meckes 513-569-7348	Soil, Sludge, Sediment	Not Applicable	Hydrocarbons, PCBs, PAHs, Pesticides, Herbicides
KAI Technologies, Inc./Brown and Root Environmental, Portsmouth, NH (008) Radio Frequency Heating	Kelly Air Force Base in San Antonio, TX/ January - July 1994	Raymond Kasevich 603-431-2266 Captain Jeff Stinson 904-283-6254 Clifton Blanchard 423-483-9900	Laurel Staley 513-569-7863	Soil	Not Applicable	Petroleum Hydrocarbons, VOCs, SVOCs, Pesticides
Magnum Water Technology, El Segundo, CA (007) CAV-OX® Process	Edwards Air Force Base, CA/ March 1993	Dale Cox 310-322-4143 Jack Simser 310-640-7000	Richard Eilers 513-569-7809	Groundwater, Wastewater	Cyanide	Halogenated Solvents, Phenol, PCP, PCBs, BTEX
Matrix Photocatalytic Inc.,** London, Ontario, Canada (009)/(E05) Photocatalytic Water Treatment	DOE's Oak Ridge Reservation in Oak Ridge, TN/ August - September 1995	Bob Henderson 519-660-8669	Richard Eilers 513-569-7809	Wastewater, Groundwater, Process Water	Nonspecific Inorganics	Most Organics
Maxymillian Technologies, Inc. (formerly Clean Berkshires, Inc.), Boston, MA (005) Thermal Desorption System	Niagara Mohawk Power Corporation Harbor Point site in Utica, NY/ November - December 1993	Neal Maxymillian 617-557-6077	Ronald Lewis 513-569-7856	Soil	Cyanide	VOCs, SVOCs, PAHs, Coal Tars
Morrison Knudsen Corporation/ Spetstamponazhgeologia Enterprises, Clay-Based Grouting Technology Boise, ID (009)	Mike Horse Mine Site in Montana/1994-1996	Kathryn Levihn Rick Raymondi 208-386-6115	Jack Hubbard 513-569-7507	Groundwater, Liquid	Heavy Metals	Nonspecific Organics

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National Risk Management Research Laboratory, Cincinnati, OH (005) Base-Catalyzed Decomposition Process	Koppers Company Superfund site in Morrisville, NC/ August - September 1993	George Huffman 513-569-7431 Yei-Shong Shieh Steven Detwiler 610-431-9100	Terrence Lyons 513-569-7589	Soil, Sediment, Sludge	Not Applicable	PCBs, PCP, Halogenated Compounds, Polychlorinated Dioxins and Furans
National Risk Management Research Laboratory, Cincinnati, OH (007) Volume Reduction Unit	Escambia Treating Company site in Pensacola, FL/ November 1992	Richard Griffiths 513-569-7832	Teri Richardson 513-569-7949	Soil	Metals	Creosote, PCP, PAHs, VOCs, SVOCs, Pesticides
National Risk Management Research Laboratory and INTECH 180 Corporation, Cincinnati, OH (006) Fungal Treatment Technology	Brookhaven Wood Preserving site in Brookhaven, MS/ June - November 1992	John Glaser 513-569-7568 Richard Lamar 801-753-2111	Teri Richardson 513-569-7949	Soil	Not Applicable	PCP, PAHs, Chlorinated Organics
National Risk Management Research Laboratory and IT Corporation, Cincinnati, OH (004) Debris Washing System	Superfund sites in Detroit, MI; Hopkinsville, KY; and Walker County, GA/ September 1988 (MI), December 1989 (KY), and August 1990 (GA)	Michael Taylor Majid Dosani 513-782-4700	Donald Sanning 513-569-7875	Debris	Nonspecific Inorganics	Nonspecific Organics, PCBs, Pesticides
National Risk Management Research Laboratory, University of Cincinnati, and FRX, Inc., Cincinnati, OH (005) Hydraulic Fracturing	Xerox Corporation site in Oak Brook, IL and an underground storage tank spill site in Dayton, OH/July 1991 - September 1992 (IL) and August 1991 - September 1992 (OH)	William Slack 513-469-6040	Michael Roulier 513-569-7796	Soil, Groundwater	Nonspecific Inorganics	Nonspecific Organics
New York State Department of Environmental Conservation/ ENSR Consulting and Engineering, and Larsen Engineers, Albany, NY (009) Ex Situ Biovault	Sweden 3-Chapman site in Sweden, NY/ July - December 1994	Nick Kolak 518-457-3372 David Ramsden 713-520-9900 N. Sathiyakumar 716-272-7310	Carolyn Acheson 513-569-7190	Soil	Not Applicable	Chlorinated and Nonchlorinated VOCs and SVOCs
New York State Department of Environmental Conservation/SBP Technologies, Inc., Albany NY (009) Vacuum-Vaporized Well System	Sweden 3-Chapman site in Sweden, NY/ July 1994 - Fall 1995	Nick Kolak 518-457-3372 Richard Desrosiers 914-694-2280	Michelle Simon 513-569-7469	Soil, Groundwater	Not Applicable	Chlorinated and Nonchlorinated VOCs

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New York State Department of Environmental Conservation/ R.E. Wright Environmental, Inc., Albany, NY (009) In Situ Bioventing Treatment System	Sweden 3-Chapman site in Sweden, NY/ July - December 1994	Nick Kolak 518-457-3372 Richard Cronce 717-944-5501	Greg Sayles 513-569-7607	Soil	Not Applicable	Chlorinated and Nonchlorinated VOCs, SVOCs
North American Technologies Group, Inc., Bellaire, TX (008) Oleophilic Amine-Coated Ceramic Chip	Petroleum Products Corporation site in Fort Lauderdale, FL/ June 1994	Alan Bell 713-662-2699	Laurel Staley 513-569-7863	Groundwater, Marine Wastes	Not Applicable	Gasoline, Crude Oil, Diesel Fuel, BTEX, PAHs, PCBs, PCP, Trichloroethene
NOVATERRA Associates, Los Angeles, CA (003) In Situ Soil Treatment (Steam and Air Stripping)	Annex Terminal in San Pedro, CA/September 1989	Phil La Mori 213-969-9788	Paul dePercin 513-569-7797	Soil, Sludge, Liquids	Nonspecific Inorganics, Heavy Metals	VOCs, SVOCs, Hydrocarbons
OHM Remediation Services Corp. (formerly offered by Chemical Waste Management, Inc.), Lombard, IL (004) X*TRAX™ Thermal Desorption	Re-Solve, Inc., Superfund site in North Dartmouth, MA/ May 1992	Chetan Trivedi 603-261-3958	Paul dePercin 513-569-7797	Soil, Sludge, Solids	Mercury, Heavy Metals	VOCs, SVOCs, PCBs, Hydrocarbons
Radian International LLC (formerly Dow Environmental, Inc.), Walnut Creek, CA (004) Integrated Vapor Extraction and Steam Vacuum Stripping	San Fernando Valley Groundwater Basin Superfund site in Burbank, CA/ September 1990	David Bluestein 510-988-1125	Gordon Evans 513-569-7684	Groundwater, Soil	Not Applicable	VOCs, Chlorinated Hydrocarbons
Remediation Technologies, Inc., Seattle, WA (002), Liquid and Solids Biological Treatment	Niagara Mohawk Power Corporation facility at Harbor Point in Utica, NY/ June-August 1995	Merv Cooper 206-624-9349	Ronald Lewis 513-569-7856	Soil, Sediment, Sludge	Not Applicable	Biodegradable Organics, Creosote, PCP, PAHs
Retech, M4 Enviromental Management Inc., Ukiah, CA (002) Plasma Arc Vitrification	DOE's Component Development and Integration Facility in Butte, MT/July 1991	Ronald Womack Leroy Leland 707-462-6522	Laurel Staley 513-569-7863	Soil, Sludge, Liquids, Solids	Heavy Metals	Nonspecific Organics
Rochem Separation Systems, Inc., Torrance, CA (006) Rochem Disc Tube™ Module System	Central Landfill Superfund site in Johnston, RI/August 1994	David LaMonica 310-370-3160	Douglas Grosse 513-569-7844	Nonspecific Liquids, Leachates	Nonspecific Inorganics	Organic Solvents

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SBP Technologies, Inc., Baton Rouge, LA (005) Membrane Filtration and Bioremediation	American Creosote Works in Pensacola, FL/October 1991	Clayton Page 504-755-7711	John Martin 513-569-7758	Groundwater, Surface Water, Storm Water, Landfill Leachates, Industrial Process Wastewater	Not Applicable	Organic Compounds, PAHs, Petroleum Hydrocarbons, TCE, PCP
J.R. Simplot Company,** Pocatello, ID (006)/(E03) The SABRE™ Process (Two Demonstrations)	Bowers Field in Ellensburg, WA and Weldon Spring Ordnance Works site in Weldon Spring, MO/ July 1993 (WA) and September 1993 - February 1994 (MO)	Russell Kaake 208-235-5620 Tom Yergovich 208-238-2850	Wendy Davis-Hoover 513-569-7206	Soil	Not Applicable	Nitroaromatics
Smith Environmental Technologies Corporation (formerly Canonic Environmental Services Corporation), Englewood, CO (006) Low Temperature Thermal Aeration (LTTA®)	Pesticide site in Phoenix, AZ/ September 1992	Joseph Hutton 303-790-1747	Paul dePercin 513-569-7797	Soil, Sludge, Sediment	Not Applicable	VOCs, SVOCs, OCPs, OPPs, TPH
SoilTech ATP Systems, Inc., Englewood, CO (005) Anaerobic Thermal Processor (Two Demonstrations)	Wide Beach Development Superfund site in Brant, NY and Waukegan Harbor Superfund site in Waukegan, IL/ May 1991 (NY); June 1992 (IL)	Joseph Hutton 303-790-1747	Paul dePercin 513-569-7797	Soil, Sludge, Sediment	Mercury	Petroleum and Halogenated Hydrocarbons, PAHs, VOCs, SVOCs
Soliditech, Inc., (002) Solidification and Stabilization	Imperial Oil Company/Champion Chemical Company Superfund site in Morganville, NJ/ December 1988	Not Available	Jack Hubbard 513-569-7507	Soil, Sludge	Metals, Nonspecific Inorganics	Nonspecific Organics, Oil and Grease
Sonotech, Inc., Atlanta, GA (007) Frequency-Tunable Pulse Combustion System	EPA's Incineration Research Facility in Jefferson, AR/ September - October 1994	Ben Zinn 404-894-3033	Marta K. Richards 513-569-7692	Soil, Sludge, Sediment, Gas	Nonspecific Inorganics	Nonspecific Organics

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STC Remediation, A Division of Omega Environmental, Inc. (formerly Silicate Technology Corporation), Scottsdale, AZ (003) Organic Stabilization and Chemical Fixation/Solidification	Selma Pressure Treating Superfund site in Selma, CA/November 1990	Scott Larsen Stephen Pegler 602-948-7100	Edward Bates 513-569-7774	Soil, Sludge, Wastewater	Heavy Metals, Cyanides, Fluorides, Arsenates, Chromates, Selenium	Nonspecific Organics, PAHs
Terra-Kleen Response Group, Inc., Del Mar, CA (006) Solvent Extraction Treatment System	Naval Air Station North Island in San Diego, CA/ May - June 1994	Alan Cash 619-558-8762	Mark Meckes 513-569-7348 Terrence Lyons 513-569-7589	Soil, Sludge, Sediment	Not Applicable	PCBs, PCP, PAH, Creosote, Chlorinated Pesticides, PCDD, PCDF
Terra Vac, Windsor, NJ (001) In Situ and Ex Situ Vacuum Extraction	Groveland Wells Superfund site in Groveland, MA/ December 1987 - April 1988	Loren Martin 609-371-0070 James Malot 787-723-9171	Not Available	Soil, Groundwater	Not Applicable	VOCs, SVOCs
Texaco Inc., S. El Monte, CA (006) Texaco Gasification Process	Developer's Montebello Research Laboratory using a mixture of soil from the Purity Oil Sales Superfund site in Fresno, CA/January 1994	John Winter 310-908-7387	Marta K. Richards 513-569-7692	Soil, Sludge, Sediment	Nonspecific Inorganics	Nonspecific Organics
Toronto Harbour Commission, (006) Soil Recycling	Toronto Port Industrial District in Toronto, Ontario, Canada/ April - May 1992	Not Available	Teri Richardson 513-569-7949	Soil	Nonspecific Inorganics	Nonspecific Organics
U.S. Filter/Zimpro, Inc. (formerly Ultrox, A Division of Zimpro Environmental, Inc., Huntington Beach, CA (003) Ultraviolet Radiation and Oxidation	Lorentz Barrel and Drum Company site in San Jose, CA/ March 1989	William Himebaugh 714-545-5557	Norma Lewis 513-569-7665	Groundwater, Leachate, Wastewater	Not Applicable	Halogenated Solvents, VOCs, Pesticides, PCBs, BTEX, PCP
United States Environmental Protection Agency, (005) Excavation Techniques and Foam Suppression Methods	McColl Superfund site in Fullerton, CA/June - July 1990	Not Available	Jack Hubbard 513-569-7507	Soil, Sludge, Sediment, Air	Metals	VOCs, SVOCs
University of Nebraska-Lincoln, Lincoln, NE (010) Center Pivot Spray Irrigation System	North Landfill Subsite in Hastings, NE/ July 1996	Ray Spalding 402-472-7558	Teri Richardson 513-569-7949	Groundwater	Not Applicable	VOCs

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WASTECH, Inc., (004) Solidification and Stabilization	Robins Air Force Base in Warner Robins, GA/ August 1991	Not Available	Terrence Lyons 513-569-7589	Soil, Sludge, Liquids	Nonspecific and Radioactive Inorganics	Nonspecific Organics
Roy F. Weston, Inc., West Chester, PA (006) Low Temperature Thermal Treatment System	Anderson Development Company Superfund site in Adrian, MI/ November - December 1991	Mike Cosmos 610-701-7423	Paul dePercin 513-569-7797	Soil, Sludge	Not Applicable	VOCs, SVOCs, Petroleum Hydrocarbons, PAHs, PCBs
Roy F. Weston, Inc./IEG Technologies, Sherman Oaks, CA (008) UVB - Vacuum Vaporizing Well	March Air Force Base, CA/ May 1993 - May 1994	Jeff Bannon 818-971-4900 Eric Klingel 704-599-4818	Michelle Simon 513-569-7469	Groundwater, Liquid, Soil	Heavy Metals	VOCs, SVOCs
Wheelabrator Clean Air Systems, Inc. (formerly Chemical Waste Management, Inc.), Schaumburg, IL (005) PO*WW*ER™ Technology	Chemical Waste Management's facility in Lake Charles, LA/ September 1992	Myron Reicher 847-706-6900	Randy Parker 513-569-7271	Wastewater, Leachate, Groundwater, Low- Level Radioactive Mixed Waste	Metals, Volatile Inorganic Compounds, Radionuclides	VOCs and Nonvolatile Organic Compounds
Xerox Corporation, Webster, NY (009) 2-PHASE™ EXTRACTION Process	McClellan Air Force Base in Sacramento, CA/ August 1994 - February 1995	Ron Hess 716-422-3694 Phil Mook 916-643-5443	Paul dePercin 513-569-7797	Groundwater, Soil, Liquid	Nonspecific Soluble Inorganics	VOCs

TABLE 1 (Continued)
Completed SITE Demonstration Program Projects as of December 1996

Developer/ Technology	Demonstration Location/ Demonstration Date	Technology Contact	EPA Project Manager	Applicable Media	Applicable Waste	
					Inorganic	Organic
ZENON Environmental Inc. (formerly Wastewater Technology Center),** Burlington, Ontario, Canada (007/E02) Cross-Flow Pervaporation System	Naval Air Station North Island in San Diego, CA/ February 1995	Chris Lipski 905-639-6320	Ronald Turner 513-569-7775	Groundwater, Leachate, Liquid	Not Applicable	Solvents, Degreasers, Gasoline, Other VOCs
ZENON Environmental Inc., Burlington, Ontario, Canada (007) ZenoGem™ Process	Nascolite Superfund site in Millville, NJ/ September - November 1994	Tony Tonelli Philip Canning 905-639-6320	Daniel Sullivan 908-321-6677	Groundwater, Leachate, Wastewater	Not Applicable	Nonspecific Organics

** From Emerging Technology Program

ACCUTECH REMEDIAL SYSTEMS, INC.
(Pneumatic Fracturing ExtractionSM and Catalytic Oxidation)

TECHNOLOGY DESCRIPTION:

Accutech Remedial Systems, Inc. (Accutech), and the Hazardous Substance Management Research Center at the New Jersey Institute of Technology in Newark, New Jersey have jointly developed an integrated treatment system that combines Pneumatic Fracturing ExtractionSM (PFESM) with catalytic oxidation. According to Accutech, the system provides a cost-effective, accelerated approach for remediating less permeable formations contaminated with halogenated and nonhalogenated volatile organic compounds (VOC) and semivolatile organic compounds (SVOC).

The Accutech system forces compressed gas into a geologic formation at pressures that exceed the

natural in situ stresses, creating a fracture network. These fractures allow subsurface air to circulate faster and more efficiently throughout the formation, which can greatly improve contaminant mass removal rates. PFESM also increases the effective area that can be influenced by each extraction well, while intersecting new pockets of contamination that were previously trapped in the formation. Thus, VOCs and SVOCs can be removed faster and from a larger section of the formation.

PFESM can be combined with a catalytic oxidation unit equipped with special catalysts to destroy halogenated organics (see photograph below). The heat from the catalytic oxidation unit can be recycled to the formation, significantly raising the vapor pressure of the contaminants. Thus, VOCs



Pneumatic Fracturing ExtractionSM and Catalytic Oxidation

and SVOCs volatilize faster, making cleanup more efficient.

PFESM can also be combined with hot gas injection (HGI), an in situ thermal process, to further enhance VOC and SVOC removal rates. HGI returns to the ground the energy generated during catalytic oxidation of the VOCs.

WASTE APPLICABILITY:

The Accutech system can remove halogenated and nonhalogenated VOCs and SVOCs from both the vadose and saturated zones. The integrated treatment system is cost-effective for treating soils and rock when less permeable geologic formations limit the effectiveness of conventional in situ technologies.

According to Accutech, the PFESM-HGI integrated treatment system is cost-effective for treating less permeable soil and rock formations where conventional in situ technologies have limited effectiveness. Activated carbon is used when contaminant concentrations decrease to levels where catalytic oxidation is no longer cost-effective.

STATUS:

The Accutech technology was accepted into the SITE Demonstration Program in December 1990. The demonstration was conducted in summer 1992 at a New Jersey Department of Environmental Protection and Energy Environmental Cleanup Responsibility Act site in Hillsborough, New Jersey. During the demonstration, trichloroethene and other VOCs were removed from a siltstone formation.

Results of this demonstration were published in the following documents available from EPA:

- Technology Evaluation Report
(EPA/540/R-93/509)
- Technology Demonstration Summary
(EPA/540/SR-93/509)
- Demonstration Bulletin
(EPA/540/MR-93/509)
- Applications Analysis Report
(EPA/540/AR-93/509)

DEMONSTRATION RESULTS:

The demonstration results indicate that PFESM increased the effective vacuum radius of influence nearly threefold. PFESM also increased the rate of mass removal up to 25 times over the rates measured using conventional extraction technology.

FOR FURTHER INFORMATION:

TECHNOLOGY DEVELOPER CONTACT:

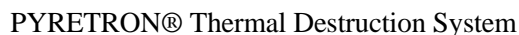
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TECHNOLOGY DESCRIPTION:

The technology fits any conventional incineration unit and can burn liquids, solids, and sludges. Solids and sludges can also be coincinerated when

WASTE APPLICABILITY:**STATUS:**

The PYRETRON® technology was demonstrated at EPA's Incineration Research Facility in Jefferson, Arkansas, using a mixture of 40 percent contaminated soil from the Stringfellow Acid Pit Superfund site in Glen Avon, California and 60 percent decanter tank tar sludge (K087) from coking operations. The demonstration began in November 1987 and was completed at the end of January 1988.



Both the Technology Evaluation Report (EPA/540/5-89/008) and Applications Analysis Report (EPA/540/A5-89/008) are available from EPA.

DEMONSTRATION RESULTS:

The polynuclear aromatic hydrocarbons naphthalene, acenaphthylene, fluorene, phenanthrene, anthracene, and fluoranthene were selected as the principal organic hazardous constituents (POHC) for the demonstration. The PYRETRON® technology achieved greater than 99.99 percent destruction and removal efficiencies for all six POHCs in all test runs. Other results are listed below:

- The PYRETRON® technology with oxygen enhancement doubled the waste throughput possible with conventional incineration.
- All particulate emission levels from the scrubber system discharge were significantly below the hazardous waste incinerator performance standard of 180 milligrams per dry standard cubic meter at 7 percent oxygen. This standard was in place until May 1993.

- Solid residues were contaminant-free.
- There were no significant differences in transient emissions of carbon monoxide between air-only incineration and PYRETRON® oxygen-enhanced operation with doubled throughput rate.
- Cost savings increase when operating and fuel costs are high and oxygen costs are relatively low.
- The system can double the capacity of a conventional rotary kiln incinerator. This increase is more significant for wastes with low heating values.

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BABCOCK & WILCOX CO. (Cyclone Furnace)

TECHNOLOGY DESCRIPTION:

The Babcock & Wilcox Co. (Babcock & Wilcox) cyclone furnace is designed to combust coal with high inorganic content (high-ash). Through cofiring, the cyclone furnace can also accommodate highly contaminated wastes containing heavy metals and organics in soil or sludge. High heat-release rates of 45,000 British thermal units (Btu) per cubic foot of coal and high turbulence in cyclones ensures the high temperatures required for melting the high-ash fuels and combusting the organics. The inert ash exits the cyclone furnace as a vitrified slag.

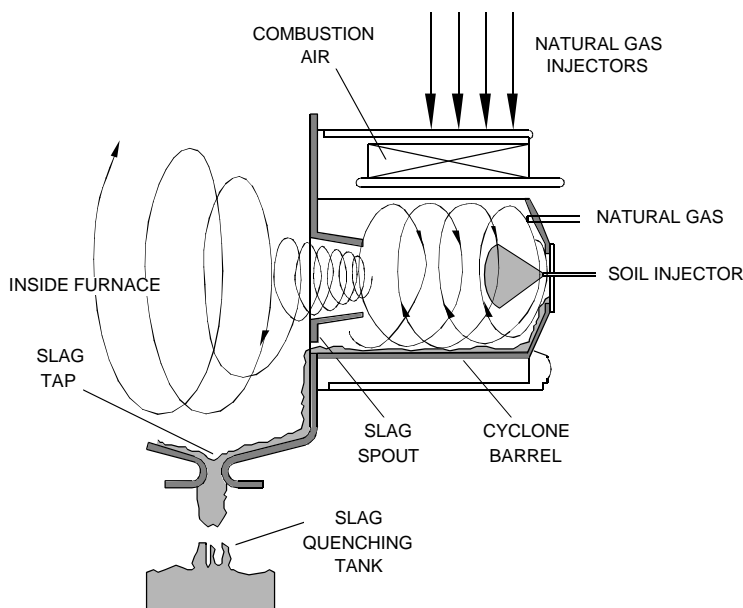
The pilot-scale cyclone furnace, shown in the figure below, is a water cooled, scaled-down version of a commercial coal-fired cyclone with a restricted exit (throat). The furnace geometry is a horizontal cylinder (barrel).

Natural gas and preheated combustion air are heated to 820 °F and enter tangentially into the cyclone burner. For dry soil processing, the soil

matrix and natural gas enter tangentially along the cyclone furnace barrel. For wet soil processing, an atomizer uses compressed air to spray the soil slurry directly into the furnace. The soil or sludge and inorganics are captured and melted, and organics are destroyed in the gas phase or in the molten slag layer. This slag layer is formed and retained on the furnace barrel wall by centrifugal action.

The soil melts, exits the cyclone furnace from the tap at the cyclone throat, and drops into a water-filled slag tank where it solidifies. A small quantity of soil also exits as fly ash with the flue gas from the furnace and is collected in a baghouse. In principle, this fly ash can be recycled to the furnace to increase metal capture and to minimize the volume of the potentially hazardous waste stream.

The energy requirements for vitrification are 15,000 Btu per pound of soil treated. The cyclone furnace can be operated with gas, oil, or coal as the supplemental fuel. If the waste is high in organic content, it may also supply a significant portion of the required fuel heat input.



Cyclone Furnace

Particulates are captured by a baghouse. To maximize the capture of particulate metals, a heat exchanger is used to cool the stack gases to approximately 200 °F before they enter the baghouse.

WASTE APPLICABILITY:

The cyclone furnace can treat highly contaminated hazardous wastes, sludges, and soils that contain heavy metals and organic constituents. The wastes may be solid, a soil slurry (wet soil), or liquids. To be treated in the cyclone furnace, the ash or solid matrix must melt (with or without additives) and flow at cyclone furnace temperatures (2,400 to 3,000 °F). Because the furnace captures heavy metals in the slag and renders them nonleachable, it is particularly suited to soils that contain lower-volatility radionuclides such as strontium and transuranics.

STATUS:

Based on results from the Emerging Technology Program, the cyclone furnace technology was accepted into the SITE Demonstration Program in August 1991. A demonstration occurred in November 1991 at the developer's facility in Alliance, Ohio. The process was demonstrated using an EPA-supplied, wet synthetic soil matrix (SSM) spiked with heavy metals (lead, cadmium, and chromium), organics (anthracene and dimethylphthalate), and simulated radionuclides (bismuth, strontium, and zirconium). Results from the demonstrations have been published in the Applications Analysis Report (EPA/520/AR-92/017) and Technology Evaluation Report, Volumes 1 and 2 (EPA/504/R-92/017A and EPA/540/R-92/017B); these documents are available from EPA.

DEMONSTRATION RESULTS:

Vitrified slag leachabilities for the heavy metals met EPA toxicity characteristic leaching procedure (TCLP) limits. TCLP leachabilities were 0.29 milligram per liter (mg/L) for lead, 0.12 mg/L for cadmium, and 0.30 mg/L for chromium. Almost 95 percent of the noncombustible SSM was incorporated into the slag. Greater than 75 percent

of the chromium, 88 percent of the strontium, and 97 percent of the zirconium were captured in the slag. Dry weight volume was reduced 28 percent. Destruction and removal efficiencies for anthracene and dimethylphthalate were greater than 99.997 percent and 99.998 percent, respectively. Stack particulates were 0.001 grain per dry standard cubic foot (gr/dscf) at 7 percent oxygen, which was below the Resource Conservation Recovery Act limit of 0.08 gr/dscf effective until May 1993. Carbon monoxide and total hydrocarbons in the flue gas were 6.0 parts per million (ppm) and 8.3 ppm, respectively.

An independent cost analysis was performed as part of the SITE demonstration. The cost to remediate 20,000 tons of contaminated soil using a 3.3-ton-per-hour unit was estimated at \$465 per ton if the unit is on line 80 percent of the time, and \$529 per ton if the unit is on line 60 percent of the time.

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BERGMANN, A DIVISION OF LINATEX, INC. (Soil and Sediment Washing)

TECHNOLOGY DESCRIPTION:

The soil and sediment washing technology developed by Bergmann, A Division of Linatex, Inc.'s, (Bergman), separates contaminated particles by density and grain size (see photograph below). The technology operates on the hypothesis that most contamination is concentrated in the fine particle fraction (less than 45 microns [μm]) and that contamination of larger particles is generally not extensive.

After contaminated soil is screened to remove coarse rock and debris, water and chemical additives such as surfactants, acids, bases, and chelators are added to the medium to produce a slurry feed. The slurry feed flows to an attrition scrubbing machine. A rotary trommel screen, dense media separators, cyclone separators, and other equipment create mechanical and fluid shear

stress, removing contaminated silts and clays from granular soil particles.

Different separation processes create the following four output streams: (1) coarse clean fraction; (2) enriched fine fraction; (3) separated contaminated humic materials; and (4) process wash water. The coarse clean fraction particles, which measure greater than 45 μm (greater than 325 mesh) each, can be used as backfill or recycled for concrete, masonry, or asphalt sand application. The enriched fine fraction particles, measuring less than 45 μm each are prepared for subsequent treatment, immobilization, destruction, or regulated disposal. Separated contaminated humic materials (leaves, twigs, roots, grasses, wood chips) are dewatered and require subsequent treatment or disposal. Upflow classification and separation, also known as elutriation, separates light contaminated materials such as leaves, twigs, roots, or wood chips. The



Bergmann Soil and Sediment Washing

process wash water is treated by flocculation and sedimentation, oil-water separation, or dissolved air flotation to remove solubilized heavy metal and emulsified organic fractions. The treated process wash water is then returned to the plant for reuse.

WASTE APPLICABILITY:

This technology is suitable for treating soils and sediment contaminated with organics, including polychlorinated biphenyls (PCB), creosote, fuel residues, and heavy petroleum; and heavy metals, including cadmium, chromium, lead, arsenic, copper, cyanides, mercury, nickel, radionuclides, and zinc.

STATUS:

This technology was accepted into the SITE Demonstration Program in winter 1991. It was demonstrated in Toronto, Ontario, Canada in April 1992 as part of the Toronto Harbour Commission (THC) soil recycling process. For further information on the THC process, including demonstration results, refer to the THC profile in the Demonstration Program section (completed projects). The technology was also demonstrated in May 1992 at the Saginaw Bay Confined Disposal Facility in Saginaw, Michigan. The Applications Analysis Report (EPA/540/AR-92/075) and the Demonstration Bulletin (EPA/540/MR-92/075) are available from EPA.

Since 1981, Bergmann has provided 31 commercial systems, treating up to 350 tons per hour, at contaminated waste sites.

DEMONSTRATION RESULTS:

Demonstration results indicate that the soil and sediment washing system can effectively isolate and concentrate PCB contamination into the organic fractions and the fines. Levels of metals contamination were also beneficially altered from the feed stream to the output streams. The effectiveness of the soil and sediment washing system on the inorganic compounds met or exceeded its performance for PCB contamination.

During a 5-day test in May 1992, the Bergmann soil and sediment washing system experienced no downtime as it operated for 8 hours per day to treat dredged sediments from the Saginaw River.

The demonstration provided the following results:

- Approximately 71 percent of the particles smaller than 45- μ m in the input sediment was apportioned to the enriched fine stream.
- Less than 20 percent of the particles smaller than 45- μ m in the input sediment was apportioned to the coarse clean fraction.
- The distribution of the concentrations of PCBs in the input and output streams were as follows:

Input sediment = 1.6 milligrams per kilogram (mg/kg)

Output coarse clean fraction = 0.20 mg/kg

Output humic materials = 11 mg/kg

Output enriched fines = 4.4 mg/kg

- The heavy metals were concentrated in the same manner as the PCBs.
- The coarse clean sand consisted of approximately 82 percent of the input sediment.

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BERKELEY ENVIRONMENTAL RESTORATION CENTER (In Situ Steam Enhanced Extraction Process)

TECHNOLOGY DESCRIPTION:

The in situ steam enhanced extraction (ISEE) process removes volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from contaminated water and soils above and below the water table (see figure below). Pressurized steam is introduced through injection wells to force steam through the soil to thermally enhance the vapor and liquid extraction processes.

The extraction wells have two purposes: (1) to pump groundwater for ex situ treatment; and (2) to transport steam and vaporized contaminants under vacuum to the surface. Recovered contaminants are condensed and recycled, processed with the contaminated groundwater, or treated in the gas phase. The ISEE process uses readily available components such as injection, extraction, and monitoring wells; manifold piping; vapor and liquid separators; vacuum pumps; and gas emission control equipment.

WASTE APPLICABILITY:

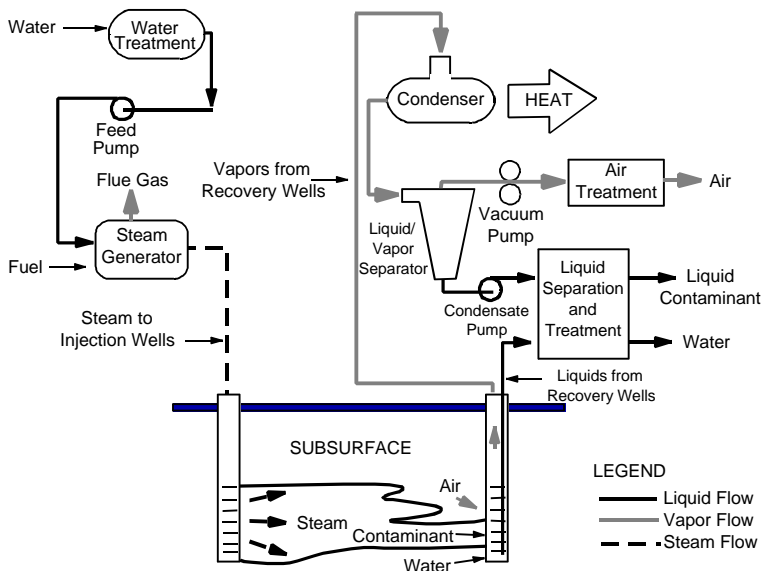
The ISEE process extracts VOCs and SVOCs from contaminated soils and groundwater. The primary compounds suitable for treatment include

hydrocarbons such as gasoline, diesel, and jet fuel; solvents such as trichloroethene, trichloroethane, and dichlorobenzene; or a mixture of these compounds. The process may be applied to contaminants above or below the water table. After treatment is complete, subsurface conditions are amenable to biodegradation of residual contaminants, if necessary. The process can be applied to contaminated soil very near the surface with a cap. Compounds denser than water may be treated only in low concentrations, unless a barrier exists or can be created to prevent downward percolation of a separate phase.

STATUS:

In August 1988, a successful pilot-scale demonstration of the ISEE process was completed at a site contaminated with a mixture of solvents. Contaminants amounting to 764 pounds were removed from the 10-foot-diameter, 12-foot-deep test region. After 5 days of steam injection, soil contaminant concentrations dropped by a factor of 10.

In December 1993, a full-scale demonstration was completed at a gasoline spill site at Lawrence Livermore National Laboratory (LLNL) in



In Situ Steam Enhanced Extraction Process

Altamont Hills, California. Gasoline was dispersed both above and below groundwater due to a 25-foot rise in the water table since the spill occurred. The lateral distribution of liquid-phase gasoline was within a region 150 feet in diameter and up to 125 feet deep. Appendix A of the Hughes Environmental Systems Innovative Technology Evaluation Report (EPA/540/R-94/510) contains detailed results from the LLNL SITE demonstration. This report is available from EPA.

A pilot-scale test of the ISEE process was conducted in 1994 at Naval Air Station (NAS) Lemoore in California. During 3 months of operation, over 98,000 gallons of JP-5 jet fuel was recovered from medium permeability, partially saturated sand to a depth of 20 feet. Preliminary soil sampling showed reductions of JP-5 jet fuel concentrations from several thousand parts per million (ppm) above the water table to values less than 25 ppm.

For more information about similar technologies, see the following profiles in the Demonstration Program section: Hughes Environmental Systems, Inc., (completed projects) and Praxis Environmental Technologies, Inc. (ongoing projects).

DEMONSTRATION RESULTS:

During the SITE demonstration at LLNL, over 7,600 gallons of gasoline were recovered from above and below the water table in 26 weeks of operation. Recovery rates were about 50 times greater than those achieved by vacuum extraction and groundwater pumping alone. The rates were highest during cyclic steam injection, after subsurface soils reached steam temperatures. The

majority of the recovered gasoline came from the condenser as a separate phase liquid or in the effluent air stream.

Without further pumping, 1,2-dichloroethene, benzene, ethylbenzene, toluene, and xylene concentrations in sampled groundwater were decreased to below maximum contaminant levels after 6 months. Post-process soil sampling indicated that a thriving hydrocarbon-degrading microbial population existed in soils experiencing prolonged steam contact.

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BILLINGS AND ASSOCIATES, INC.

(Subsurface Volatilization and Ventilation System [SVVS®])

TECHNOLOGY DESCRIPTION:

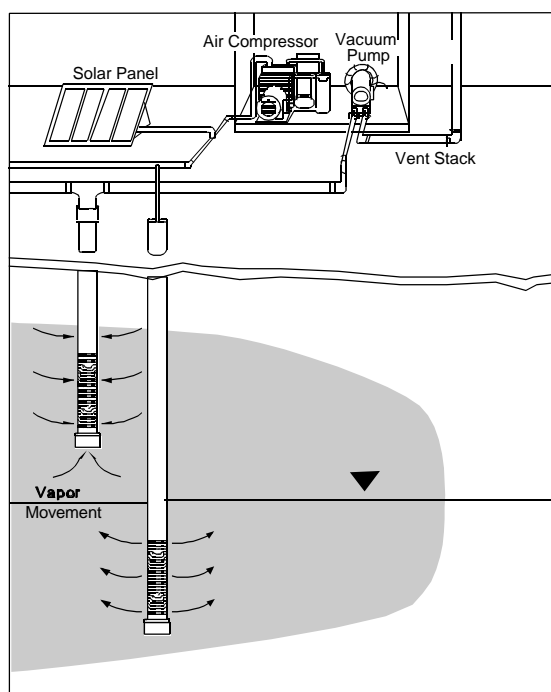
The Subsurface Volatilization and Ventilation System (SVVS®), developed by Billings and Associates, Inc. (BAI), and operated by several other firms under a licensing agreement, uses a network of injection and extraction wells (collectively called a reactor nest) to treat subsurface organic contamination through soil vacuum extraction combined with in situ biodegradation. Each system is designed to meet site-specific conditions.

The SVVS® is shown in the figure below. A series of injection and extraction wells is installed at a site. One or more vacuum pumps create negative pressure to extract contaminant vapors, while an air compressor simultaneously creates positive pressure, sparging the subsurface treatment area. Control is maintained at a vapor control unit that houses pumps, control valves, gauges, and other process control hardware. At most sites with subsurface organic contamination, extraction wells are placed above the water table and injection wells

are placed below the groundwater. This placement allows the groundwater to be used as a diffusion device.

The number and spacing of the wells depends on the modeling results of a design parameter matrix, as well as the physical, chemical, and biological characteristics of the site. The exact depth of the injection wells and screened intervals are additional design considerations.

To enhance vaporization, solar panels are occasionally used to heat the injected air. Additional valves for limiting or increasing air flow and pressure are placed on individual reactor nest lines (radials) or, at some sites, on individual well points. Depending on groundwater depths and fluctuations, horizontal vacuum screens, "stubbed" screens, or multiple-depth completions can be applied. Positive and negative air flow can be shifted to different locations at the site to emphasize remediation on the most contaminated areas. Negative pressure is maintained at a suitable level to



Subsurface Volatilization and Ventilation System (SVVS®)

prevent escape of vapors.

Because it provides oxygen to the subsurface, the SVVS® can enhance in situ bioremediation at a site, thereby decreasing remediation time. These processes are normally monitored by measuring dissolved oxygen levels in the aquifer, recording carbon dioxide levels in transmission lines and at the emission point, and periodically sampling microbial populations. When required by air quality permits, volatile organic compound emissions can be treated by a patent-pending biological filter that uses indigenous microbes from the site.

WASTE APPLICABILITY:

The SVVS® is applicable to soils, sludges, and groundwater contaminated with gasoline, diesel fuels, and other hydrocarbons, including halogenated compounds. The technology is effective on benzene, toluene, ethylbenzene, and xylene contamination. It can also contain contaminant plumes through its unique vacuum and air injection techniques.

STATUS:

This technology was accepted into the SITE Demonstration Program in winter 1991. A site in Buchanan, Michigan was selected for the demonstration, and initial drilling and construction began in July 1992. The demonstration began in March 1993 and was completed in May 1994. The Demonstration Bulletin (EPA/540/MR-94/529), Technology Capsule (EPA/540/R-94/529a), and Innovative Technology Evaluation Report (EPA/540/R-94/529) are available from EPA. The SVVS® has also been implemented at 75 underground storage tank sites in New Mexico, North Carolina, South Carolina, and Florida.

BAI is researching ways to increase the microbiological effectiveness of the technology and is testing a mobile unit. The mobile unit will allow rapid field pilot tests to support the design process. This unit will also permit actual remediation of small sites and of small, recalcitrant areas on large sites.

DEMONSTRATION RESULTS:

Results from the SVVS® demonstration are as follows:

- Data indicated that the overall reductions for several target analytes, as determined from individual boreholes, ranged from 71 percent to over 99 percent, over a 1-year period.
- The early phase of the remediation was characterized by higher concentrations of volatile organics in the extracted vapor stream.
- The shutdown tests indicate that the technology stimulated biodegradative processes at the site.

FOR FURTHER INFORMATION:

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BIOGENESIS ENTERPRISES, INC. (BioGenesisSM Soil and Sediment Washing Process)

TECHNOLOGY DESCRIPTION:

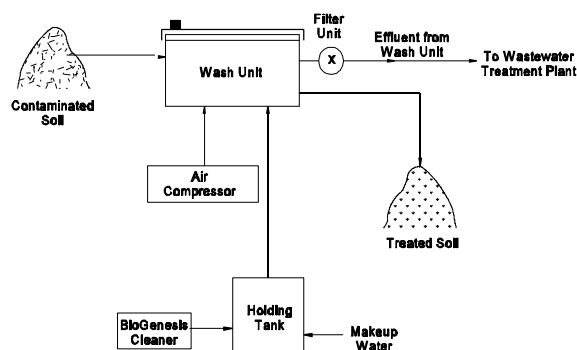
The BioGenesisSM soil and sediment washing process uses specialized, patent-pending equipment, complex surfactants, and water to clean soil, sediment, and sludge contaminated with organic and inorganic constituents. Two types of mobile equipment wash different sizes of particles. A truck-mounted batch unit processes 20 yards per hour, and washes soil particles 10 mesh and larger. A full-scale, mobile, continuous flow unit cleans sand, silt, clay, and sludge particles smaller than 10 mesh at a rate of 20 to 40 yards per hour. Auxiliary equipment includes tanks, dewatering and water treatment equipment, and a bioreactor. Extraction efficiencies per wash cycle range from 85 to 99 percent. High contaminant levels require multiple washes.

The principal components of the process consist of pretreatment equipment for particle sizing, a truck-mounted soil washer for larger particles, a sediment washing unit(s) for fine particles, and water treatment and reconditioning equipment. The BioGenesisSM soil washing system for larger particles consists of a trailer-mounted gondola plumbed for air mixing, water and chemical addition, oil skimming, and liquid drainage (see figure below). Water, BioGenesisSM cleaning

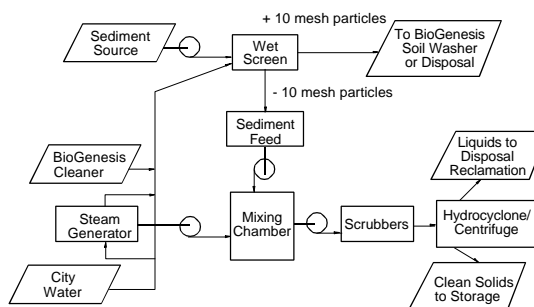
chemicals, and soil are loaded into the gondola. Aeration nozzles feed compressed air to create a fluidized bed. The resulting slurry is agitated to release organic and inorganic contaminants from the soil particles. After mixing, a short settling period allows the soil particles to sink and the removed oil to rise to the water surface, where it is skimmed for reclamation or disposal. Following drainage of the wash water, the treated soil is evacuated by raising the gondola's dump mechanism. Processed soil contains a moisture level of 10 to 20 percent depending on the soil matrix.

A prototype BioGenesisSM sediment washing machine was tested in Environment Canada's Contaminated Sediment Treatment Technology Program. The sediment washing machine is a continuous flow unit. Capacities of up to 80 to 100 cubic yards per hour are possible using full-scale, parallel processing equipment.

In the sediment washing machine, sediment is pretreated to form a slurry. The slurry passes to a shaker screen separator that sizes particles into two streams. Material greater than 1 millimeter (mm) in diameter is diverted to the large particle soil washer. Material 1 mm and smaller continues to the sediment washer's feed hopper. From there, the slurry is injected to the sediment cleaning chamber



Soil Washing Process



Sediment Washing Process

to loosen the bonds between the pollutant and the particle.

After the cleaning chamber, the slurry flows to the scrubber to further weaken the bonds between contaminants and particles. After the scrubber, the slurry passes through a buffer tank, where large particles separate by gravity. The slurry then flows through hydrocyclone banks to separate solids down to 3 to 5 microns in size. The free liquid routes to a centrifuge for final solid-liquid separation. All solids go to the treated soil pile; all liquid is routed to wastewater treatment to remove organic and inorganic contaminants. Decontaminated wastewater is recycled back through the process. Equipment configuration varies depending on the soil matrix.

The BioGenesisTM cleaning chemical is a light alkaline mixture of ionic and nonionic surfactants and bioremediating agents that act similarly to a biosurfactant. The proprietary cleaner contains no hazardous ingredients.

WASTE APPLICABILITY:

This technology extracts many inorganics, volatile and nonvolatile hydrocarbons, chlorinated hydrocarbons, pesticides, polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons, and most organics from nearly every soil and sediment type, including clay.

STATUS:

The BioGenesisSM soil washing technology was accepted into the SITE Demonstration Program in June 1990. The process was demonstrated in November 1992 on weathered crude oil at a refinery site in Minnesota. Results from the demonstration have been published in the Innovative Technology Evaluation Report (EPA/540/R-93/510) and the SITE Technology Capsule (EPA/540/SR-93/510). The reports are available from EPA. BioGenesis Enterprises, Inc., is planning a future demonstration of the BioGenesisSM sediment washing process using PCB-contaminated sediment.

DEMONSTRATION RESULTS:

Results of the SITE demonstration are presented below:

- Soil washing and biodegradation with BioGenesisSM removed about 85 percent of the total recoverable petroleum hydrocarbon (TRPH)-related contaminants in the soil.
- Treatment system performance was reproducible at constant operating conditions.
- At the end of 90 days, TRPH concentrations decreased an additional 50 percent compared to washing alone.
- The prototype equipment operated within design parameters. New production equipment is expected to streamline overall operating efficiency.

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BIO-REM, INC.

(Augmented In Situ Subsurface Bioremediation Process)

TECHNOLOGY DESCRIPTION:

The Bio-Rem, Inc., Augmented In Situ Subsurface Bioremediation Process uses a proprietary blend (H-10) of microaerophilic bacteria and micronutrients for subsurface bioremediation of hydrocarbon contamination in soil and water (see figure below). The insertion methodology is adaptable to site-specific situations. The bacteria are hardy and can treat contaminants in a wide temperature range. The process does not require additional oxygen or oxygen-producing compounds, such as hydrogen peroxide. Degradation products include carbon dioxide and water.

The bioremediation process consists of four steps: (1) defining and characterizing the contamination plume; (2) selecting a site-specific application methodology; (3) initiating and propagating the bacterial culture; and (4) monitoring and reporting

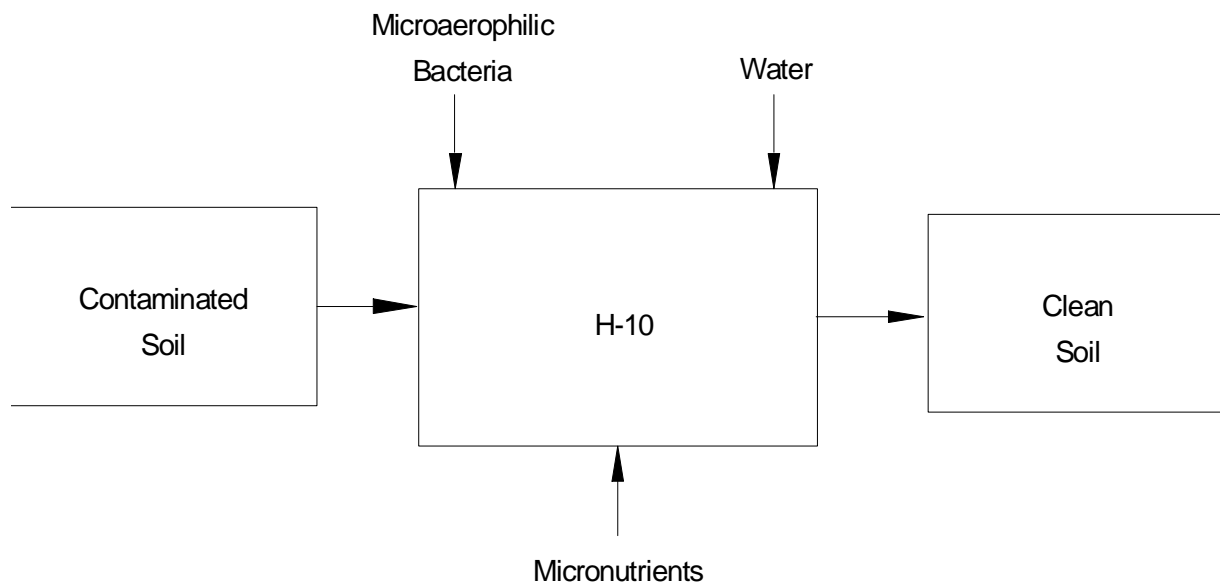
cleanup.

WASTE APPLICABILITY:

This technology treats soil and water contaminated with hydrocarbons, including halogenated hydrocarbons.

STATUS:

This technology was accepted into the SITE Demonstration Program in winter 1991. The technology was demonstrated at Williams Air Force Base in Phoenix, Arizona from May 1992 through June 1993. The Demonstration Bulletin (EPA/540/MR-93/527) is available from EPA. Bio-Rem, Inc., has remediated sites in Illinois, Michigan, Indiana, Texas, Kentucky, Ohio, Arizona, Connecticut, Florida, Georgia, Vermont, Oklahoma, Virginia, Nevada, California, Missouri, and



Augmented In Situ Subsurface Bioremediation Process

Washington.

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BIOTROL® (Biological Aqueous Treatment System)

TECHNOLOGY DESCRIPTION:

The BioTrol biological aqueous treatment system (BATS) is a patented biological system that treats contaminated groundwater and process water. The system uses naturally occurring microbes; in some instances, however, a specific microorganism may be added. This technique, known as microbial amendment, is important if a highly toxic or recalcitrant target compound is present. The amended microbial system removes both the target contaminant and the background organic carbon.

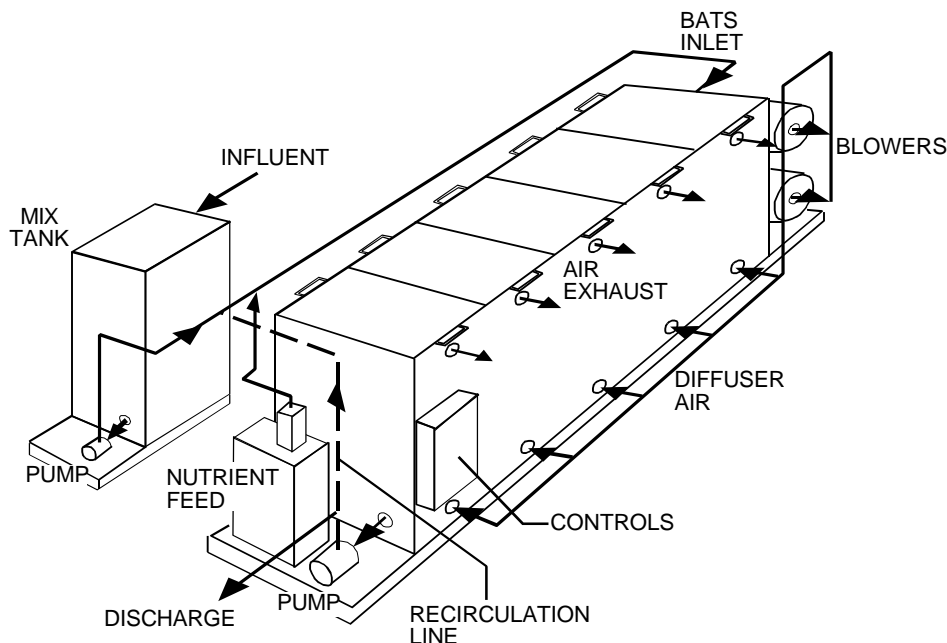
The figure below is a schematic of the BATS. Contaminated water enters a mix tank, where the pH is adjusted and inorganic nutrients are added. If necessary, the water is heated to an optimum temperature with a heater and a heat exchanger, to minimize energy costs. The water then flows to the bioreactor, where the contaminants are biodegraded.

The microorganisms that degrade the contaminants are immobilized in a multiple-cell, submerged, fixed-film bioreactor. Each cell is filled with a highly porous packing material to which the microbes adhere. For aerobic conditions, air is supplied by fine bubble membrane diffusers mounted at the bottom of each cell. The system may also run under anaerobic conditions.

As water flows through the bioreactor, the contaminants are degraded to biological end-products, predominantly carbon dioxide and water. The resulting effluent may be discharged to a publicly owned treatment works or reused on site. In some cases, discharge with a National Pollutant Discharge Elimination System permit may be possible.

WASTE APPLICABILITY:

The BATS may be applied to a wide variety of wastewaters, including groundwater, lagoons, and



BioTrol Biological Aqueous Treatment System (BATS)

process water. Contaminants amenable to treatment include pentachlorophenol (PCP), creosote components, gasoline and fuel oil components, chlorinated hydrocarbons, phenolics, and solvents. Other potential target waste streams include coal tar residues and organic pesticides. The BATS may also be effective for treating certain inorganic compounds such as nitrates; however, this application has not yet been demonstrated. The system does not treat metals.

STATUS:

The BATS was accepted into the SITE Demonstration Program in 1989. The system was demonstrated under the SITE Program from July to September 1989 at the MacGillis and Gibbs Superfund site in New Brighton, Minnesota. The system operated continuously for 6 weeks at three different flow rates. The Applications Analysis Report (EPA/540/A5-91/001), the Technology Evaluation Report (EPA/540/5-91/001), and the Demonstration Bulletin (EPA/540/M5-91/001) are available from EPA.

During 1986 and 1987, BioTrol performed a successful 9-month pilot-scale field test of the BATS at a wood preserving facility. Since that time, the firm has installed more than 20 full-scale systems and has performed several pilot-scale demonstrations. These systems have successfully treated waters contaminated with gasoline, mineral spirit solvents, phenol, and creosote.

DEMONSTRATION RESULTS:

For the SITE demonstration, the BATS yielded the following results:

- Reduced PCP concentrations from about 45 parts per million (ppm) to 1 ppm or less in a single pass
- Produced minimal sludge and no PCP air emissions
- Mineralized chlorinated phenolics
- Eliminated groundwater biotoxicity
- Appeared to be unaffected by low concentrations of oil and grease (about 50 ppm) and heavy metals in groundwater
- Required minimal operator attention

The treatment cost per 1,000 gallons was \$3.45 for a 5-gallon-per-minute (gpm) pilot-scale system and \$2.43 for a 30-gpm system.

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BIOTROL® (Soil Washing System)

TECHNOLOGY DESCRIPTION:

The BioTrol Soil Washing System is a patented, water-based volume reduction process used to treat excavated soil. The system may be applied to contaminants concentrated in the fine-sized soil fraction (silt, clay, and soil organic matter) or in the coarse soil fraction (sand and gravel).

In the first part of the process, debris is removed from the soil. The soil is then mixed with water and subjected to various unit operations common to the mineral processing industry (see figure below). The equipment used in these operations can include mixing trommels, pug mills, vibrating screens, froth flotation cells, attrition scrubbing machines, hydrocyclones, screw classifiers, and various dewatering apparatus.

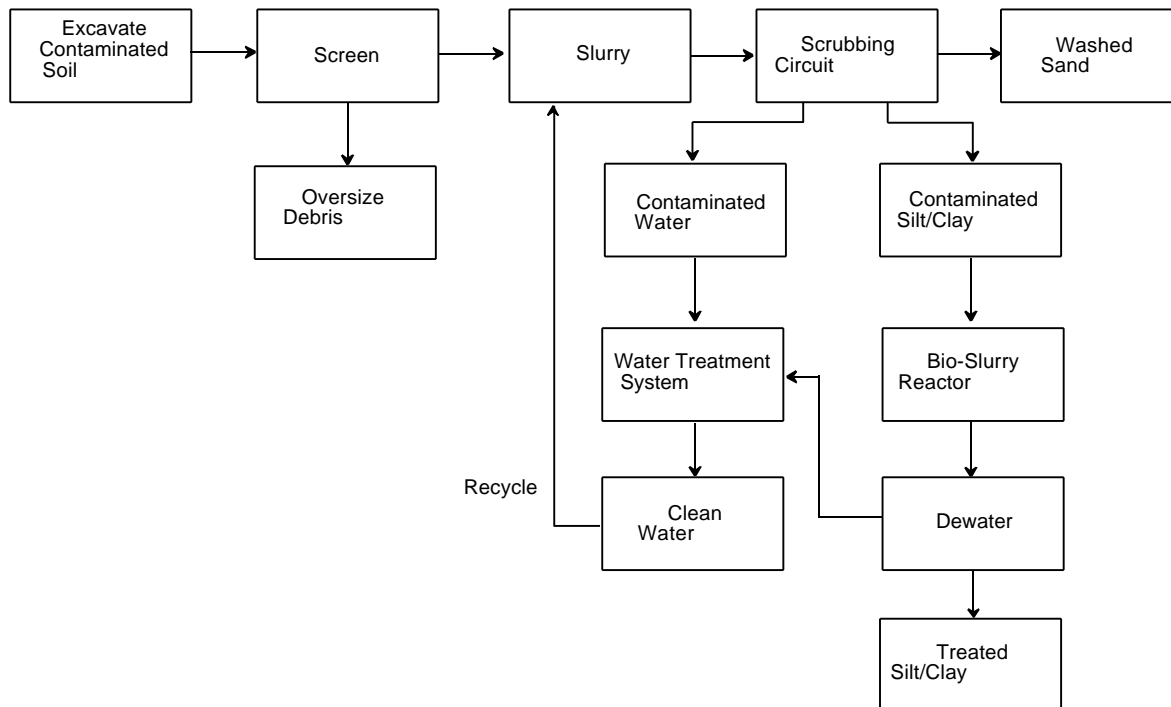
The core of the process is a multistage, counter-current, intensive scrubbing circuit with interstage classification. The scrubbing action disintegrates

soil aggregates, freeing contaminated fine particles from the coarser material. In addition, surficial contamination is removed from the coarse fraction by the abrasive scouring action of the particles themselves. Contaminants may also be solubilized, as dictated by solubility characteristics or partition coefficients.

Contaminated residual products can be treated by other methods. Process water is normally recycled after biological or physical treatment. Contaminated fines may be disposed of off site, incinerated, stabilized, or biologically treated.

WASTE APPLICABILITY:

This system was initially developed to clean soils contaminated with wood preserving wastes, such as polynuclear aromatic hydrocarbons (PAH) and pentachlorophenol (PCP). The system may also apply to soils contaminated with petroleum hydrocarbons, pesticides, polychlorinated biphenyls,



BioTrol Soil Washing System Process Diagram

various industrial chemicals, and metals.

STATUS:

The BioTrol Soil Washing System was accepted into the SITE Demonstration Program in 1989. The system was demonstrated under the SITE Program between September and October 1989 at the MacGillis and Gibbs Superfund site in New Brighton, Minnesota. A pilot-scale unit with a treatment capacity of 500 pounds per hour operated 24 hours per day during the demonstration. Feed for the first phase of the demonstration (2 days) consisted of soil contaminated with 130 parts per million (ppm) PCP and 247 ppm total PAHs; feed for the second phase (7 days) consisted of soil containing 680 ppm PCP and 404 ppm total PAHs.

Contaminated process water was treated biologically in a fixed-film reactor and recycled. A portion of the contaminated soil fines was treated biologically in a three-stage, pilot-scale EIMCO Biolift™ reactor system supplied by the EIMCO Process Equipment Company. The Applications Analysis Report (EPA/540/A5-91/003) and the Technology Evaluation Report Volume I (EPA/540/5-91/003a) and Volume II (EPA/540/5-91/003b and EPA/540/5-91/003c) are available from EPA.

DEMONSTRATION RESULTS:

Key findings from the BioTrol demonstration are summarized below:

- Feed soil (dry weight basis) was successfully separated into 83 percent washed soil, 10 percent woody residues, and 7 percent fines. The washed soil retained about 10 percent of the feed soil contamination; 90 percent of this contamination was contained within the woody residues, fines, and process wastes.
- The multistage scrubbing circuit removed up to 89 percent PCP and 88 percent total PAHs, based on the difference between concentration levels in the contaminated (wet) feed soil and the washed soil.
- The scrubbing circuit degraded up to 94 percent PCP in the process water during soil washing. PAH removal could not be determined because of low influent concentrations.
- The cost of a commercial-scale soil washing system, assuming use of all three technologies (soil washing, water treatment, and fines treatment), was estimated to be \$168 per ton. Incineration of woody material accounts for 76 percent of the cost.

FOR FURTHER INFORMATION:

TECHNOLOGY DEVELOPER CONTACT:

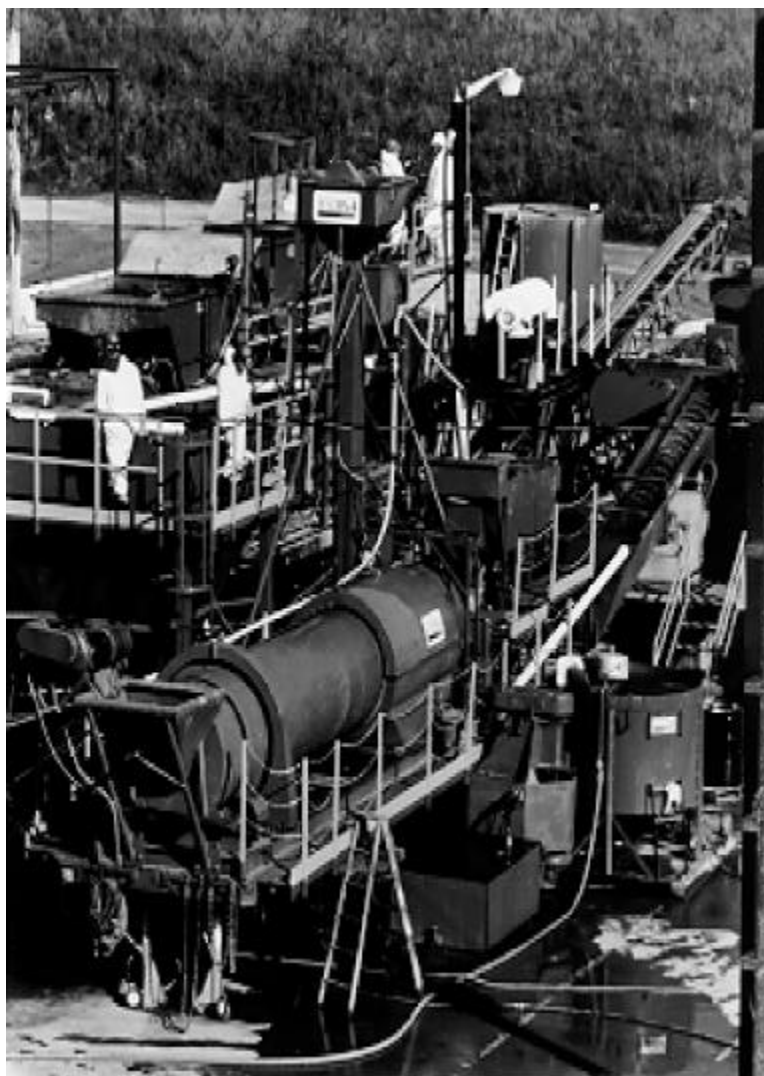
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BRICE ENVIRONMENTAL SERVICES CORPORATION (Soil Washing Process)

TECHNOLOGY DESCRIPTION:

Brice Environmental Services Corporation (BESCORP) has developed a portable aboveground soil washing process that reduces the overall volume of contaminated soil requiring treatment. BESCORP's soil washing process involves site-specific unit operations, the selection of which depend on soil and contaminant characteristics,

cleanup standards, cost, and client specifications. The process includes a volume reduction operation, in which oversized soil is cleaned by intensive scrubbing, followed by density, magnetic, and size separations. During volume reduction, contaminants that exist as discrete or attrited particles are partitioned with the soil fines, while the process water is recirculated and treated to remove suspended and dissolved contaminants.



BESCORP Soil Washing Plant

BESCOP's small volume reduction plant, used for demonstration and pilot testing, is contained on one trailer and has a variable process rate from 4 to 20 tons per hour, depending on soil and contaminant characteristics. A full-scale plant (see photograph on previous page) has operated successfully since 1993, averaging 15 tons per hour during summer 1994 field activities.

WASTE APPLICABILITY:

The BESCOP soil washing process can treat soils contaminated with radioactive and heavy metals. It can be combined with chemical treatment technologies for complete soil remediation. BESCOP has also built a soil washing plant to remediate hydrocarbon-contaminated soil.

STATUS:

The BESCOP soil washing process was accepted into the SITE Demonstration Program in winter 1991. Under the program, the BESCOP system was demonstrated in late summer 1992 on lead-contaminated soil at the Alaskan Battery Enterprises (ABE) Superfund site in Fairbanks, Alaska. The Demonstration Bulletin (EPA/540/MR-93/503) and the Applications Analysis Report (EPA/540/A5-93/503) are available from EPA.

The BESCOP soil washing process was also linked with a chemical treatment process developed by COGNIS, Inc., to remove heavy metals from contaminated soil at the Twin Cities Army Ammunition Plant (TCAAP) Site F in New Brighton, Minnesota. At Site F, BESCOP and COGNIS, Inc., treated lead, copper, and several other heavy metals to soil cleanup criteria. The technologies treated feed soils containing lead in concentrations from 3,000 to 10,000 parts per million (ppm) to under 300 ppm in a continuous 12- to 15-ton-per-hour process. The full-scale, combined system processed contaminated soil from September 1993 through August 1995.

For further information on the COGNIS, Inc., TERRAMET® chemical treatment process, refer to the profile in the Demonstration Program section (completed projects).

DEMONSTRATION RESULTS:

The demonstration at the ABE site consisted of three test runs using the BESCOP small volume reduction plant, averaging 5 hours in duration; 48 tons of soil were processed. Results from the demonstration include the following:

- Feed soils averaged 4,500 ppm lead, and the processed, separated fines fraction averaged 13,000 ppm lead.
- On-line reliability was 92 percent.
- Lead removal from the combined gravel and sand fractions during the three runs was 61, 93, and 85 percent.
- Large quantities of metallic lead (battery casings) discovered in the excavated soil made it necessary to modify the system by employing density separation equipment. The processed sand and gravel in Run 3 contained no metallic lead.
- Gravel produced by all three runs met toxicity characteristic leaching procedure (TCLP) criteria, with average lead concentrations in the TCLP leachate at 1.0, 0.8, and 0.2 milligram per liter.
- Battery casings removal efficiencies during the three runs were 94, 100, and 90 percent.

Results from the demonstration at TCAAP Site F indicate that the BESCOP process reduced the lead load to the TERRAMET® process by 39 to 63 percent.

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CALGON CARBON OXIDATION TECHNOLOGIES (formerly **VULCAN PEROXIDATION SYSTEMS, INC.**) (**perox-pure™ Chemical Oxidation Technology**)

TECHNOLOGY DESCRIPTION:

The **perox-pure™** treatment system is designed to destroy dissolved organic contaminants in groundwater or wastewater with an advanced chemical oxidation process that uses ultraviolet (UV) radiation and hydrogen peroxide. Hydrogen peroxide is added to the contaminated water, and the mixture is then fed into the treatment system.

The treatment system's oxidation section contains one or more reaction chambers. Each chamber contains one high-intensity UV lamp mounted in a quartz sleeve. The contaminated water flows in the space between the chamber wall and the quartz sleeve in which each UV lamp is mounted. The **perox-pure™** equipment includes circular wipers attached to the quartz sleeves. These wipers periodically remove solids that may accumulate on the sleeves, a feature designed to maintain maximum treatment efficiency.

UV light catalyzes chemical oxidation of organic contaminants in water by affecting the organics so they react with hydrogen peroxide. Many organic contaminants that absorb UV light change chemically or become more reactive with chemical oxidants. More importantly, UV light catalyzes hydrogen peroxide breakdown to produce hydroxyl radicals, which are powerful chemical oxidants. Hydroxyl radicals react with and destroy organic contaminants, ultimately producing harmless by-products such as carbon dioxide, halides, and water. The treatment system produces no air emissions.

WASTE APPLICABILITY:

The **perox-pure™** technology treats groundwater and wastewater contaminated with chlorinated solvents, pesticides, polychlorinated biphenyls, phenolics, ethers, fuel hydrocarbons, and other organic compounds. It is effective on



perox-pure™ Model SSB-30

concentrations ranging from low parts per billion to several hundred parts per million (ppm). In certain instances, when used in conjunction with photocatalysts, it can be competitive for contaminated concentrations of several thousand ppm. In some cases, the combination of the **perox-pure™** technology with activated carbon, air stripping, or biological treatment will provide a more economical approach than would be obtained by using only one technology.

STATUS:

The **perox-pure™** technology was accepted into the SITE Demonstration Program in April 1991. A Model SSB-30 (see photograph on previous page) was demonstrated in September 1992 at the Lawrence Livermore National Laboratory Superfund site in Altamont Hills, California. The purpose of this demonstration was to measure how well the **perox-pure™** technology removed volatile organic compounds from contaminated groundwater at the site. The Demonstration Bulletin (EPA/540/MR-93/501), Technology Demonstration Summary (EPA/540/SR-93/501), Applications Analysis Report (EPA/540/AR-93/501), and Technology Evaluation Report (EPA/540/R-93/501) are available from EPA.

This technology has been successfully applied to over 150 sites throughout the United States, Canada, the Far East, and Europe. The treatment units at these sites have treated contaminated groundwater, industrial wastewater, contaminated drinking water, landfill leachates, and industrial reuse streams (process waters). Equipment treatment rates range from several gallons to several thousand gallons per minute.

DEMONSTRATION RESULTS:

Operating parameters for the treatment system were varied during the demonstration. Three reproducibility tests were performed at the optimum operating conditions, which were selected from the initial test runs.

In most cases, the **perox-pure™** technology reduced trichloroethene, tetrachloroethene, chloroform, trichloroethane, and dichloroethane to below analytical detection limits. For each organic contaminant, the **perox-pure™** technology complied with California action levels and federal drinking water maximum contaminant levels at the 95 percent confidence level. The quartz sleeve wipers effectively cleaned the sleeves and eliminated the interference caused by tube scaling.

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CF SYSTEMS CORPORATION (Liquified Gas Solvent Extraction [LG-SX] Technology)

TECHNOLOGY DESCRIPTION:

The CF Systems Corporation (CF Systems) liquified gas solvent extraction (LG-SX) technology uses liquified gas solvents to extract organics from soils, sludges, sediments, and wastewaters. Gases, when liquified under pressure, have unique physical properties that enhance their use as solvents. The low viscosities, densities, and surface tensions of these gases result in significantly higher rates of extraction compared to conventional liquid solvents. These enhanced physical properties also accelerate treated water's gravity settling rate following extraction. Due to their high volatility, gases are also easily recovered from the suspended solids matrix, minimizing solvent losses.

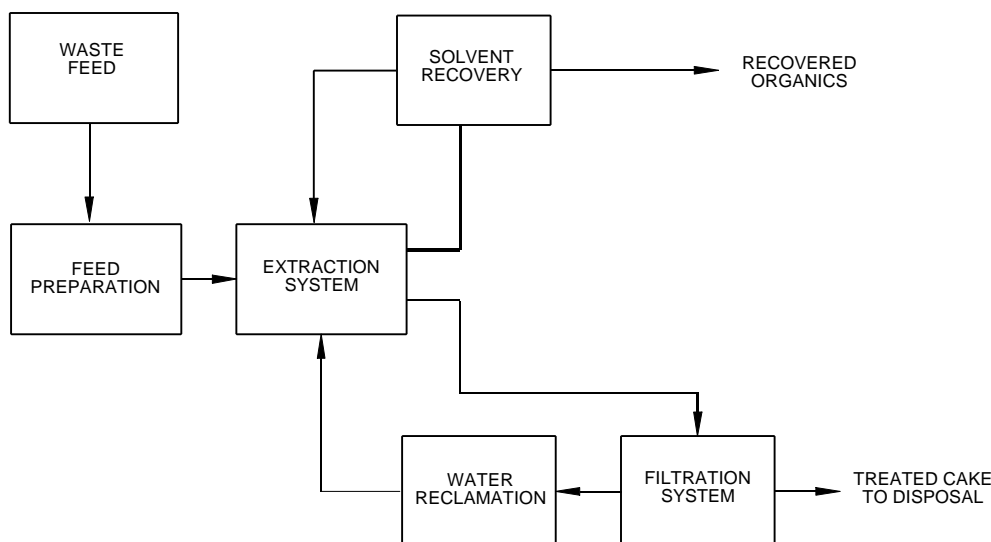
Liquified propane solvent is typically used to treat soils, sludges, and sediments, while liquified carbon dioxide is typically used to treat wastewater. The extraction system uses a batch extractor-decanter design for solids and sludges and a continuous trayed tower design for waste-waters and low-solids wastes. Typical treatment costs for non-pumpable soils and sludges range

from \$80 to \$300 per ton of feed, excluding excavation and disposal.

Contaminated solids, slurries, or wastewaters are fed into the extraction system along with solvent (see figure below). Typically, more than 99 percent of the organics are extracted from the feed. After the solvent and organics are separated from the treated feed, the solvent and organic mixture passes to the solvent recovery system. Once in the solvent recovery system, the solvent is vaporized and recycled as fresh solvent. The organics are drawn off and either reused or disposed of. Treated feed is discharged from the extraction system as a slurry. The slurry is filtered and dewatered. The reclaimed water is recycled to the extraction system and the filter cake is sent to disposal or reused.

WASTE APPLICABILITY:

The LG-SX technology can be applied to soils and sludges containing volatile and semivolatile organic compounds and other higher boiling point complex organics, such as polynuclear aromatic hydrocarbons (PAH), polychlorinated biphenyls



Liquified Gas Solvent Extraction (LG-SX) Technology

(PCB), dioxins, and pentachlorophenol (PCP). This process can also treat refinery wastes and wastewater contaminated with organics.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1988. Under the SITE Program, a pilot-scale mobile demonstration unit was tested in September 1988 on PCB-laden sediments from the New Bedford Harbor Superfund site in Massachusetts. PCB concentrations in the harbor sediment ranged from 300 parts per million (ppm) to 2,500 ppm. The Technology Evaluation Report (EPA/540/5-90/002) and the Applications Analysis Report (EPA/540/A5-90/002) are available from EPA.

A pilot-scale treatability study was completed on PCB-contaminated soil from a Michigan Superfund site. Analytical data showed that the treatment reduced PCB levels to below 5 ppm, representing a 98 percent removal efficiency for this waste. A Project Summary (EPA/540/SR-95/505), which details results from this work, is available from EPA.

CF Systems completed the first commercial on-site treatment operation at Star Enterprise in Port Arthur, Texas. The propane-based solvent extraction unit processed listed refinery K- and F-wastes, producing Resource Conservation and Recovery Act treated solids that met EPA land-ban requirements. The unit operated continuously from March 1991 to March 1992 and was on-line more than 90 percent of the time. Following heavy metals fixation, the treated solids were disposed of in a Class I landfill.

EPA Region 6 and the Texas Natural Resources Conservation Commission selected the LG-SX technology to clean an estimated 115,000 tons of contaminated soil at the United Creosoting Superfund Site in Conroe, Texas. The 250 tons per day unit is on site and is anticipated to begin full scale operation in December 1996. The soil is contaminated with PAHs, PCP, and chlorinated isomers of furan and dioxin.

DEMONSTRATION RESULTS:

This technology was demonstrated concurrently with dredging studies managed by the U.S. Army Corps of Engineers. Contaminated sediments were treated by the LG-SX technology, using a liquified propane and butane mixture as the extraction solvent. The demonstration at the New Bedford site yielded the following results:

- Extraction efficiencies were 90 to 98 percent for sediments containing PCBs between 360 and 2,575 ppm. PCB concentrations were as low as 8 ppm in the treated sediment.
- Volatile and semivolatile organics in aqueous and semisolid wastes were extracted with 99.9 percent efficiency.
- Operating problems included solids retention in the system hardware and foaming in receiving tanks. The problems were corrected in the full-scale operations at Star Enterprise.
- Projected costs for PCB cleanup were estimated at \$150 to \$450 per ton, including material handling and pre- and posttreatment costs. These costs are highly dependent on the utilization factor and job size, which may result in lower costs for large cleanups.

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CHEMFIX TECHNOLOGIES, INC. (Solidification and Stabilization)

TECHNOLOGY DESCRIPTION:

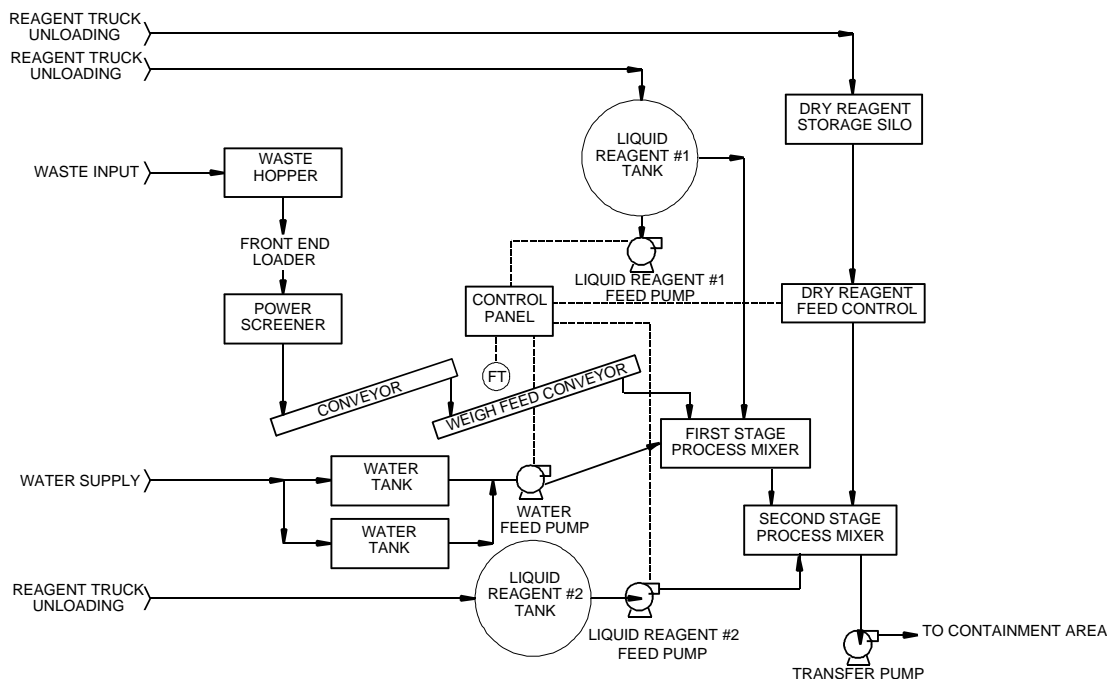
In this solidification and stabilization process, pozzolanic materials react with polyvalent metal ions and other waste components to produce a chemically and physically stable solid material. Optional binders and reagents may include soluble silicates, carbonates, phosphates, and borates. The end product may be similar to a clay-like soil, depending on the characteristics of the raw waste and the properties desired in the end product.

The figure below illustrates the Chemfix Technologies, Inc. (Chemfix), process. Typically, the waste is first blended in a reaction vessel with pozzolanic materials that contain calcium hydroxide. This blend is then dispersed throughout an aqueous phase. The reagents react with one another and with toxic metal ions, forming both anionic and cationic metal complexes. Pozzolans that accelerate and other reagents that precipitate metals can be added before or after the dry binder is initially mixed with the waste.

When a water soluble silicate reacts with the waste and the pozzolanic binder system, colloidal silicate gel strengths are increased within the binder-waste matrix, helping to bind polyvalent metal cations. A large percentage of the heavy metals become part of the calcium silicate and aluminate colloidal structures formed by the pozzolans and calcium hydroxide. Some of the metals, such as lead, adsorb to the surface of the pozzolanic structures. The entire pozzolanic matrix, when physically cured, decreases toxic metal mobility by reducing the incursion of leaching liquids into and out of the stabilized matrices.

WASTE APPLICABILITY:

This process is suitable for contaminated soils, sludges, ashes, and other solid wastes. The process is particularly applicable to electroplating sludges, electric arc furnace dust, heavy metal contaminated soils, oil field drilling muds and cuttings, municipal sewage sludges, and residuals from other treatment processes. This process effectively treats heavy



Process Flow Diagram

metals, such as antimony, arsenic, lead, cadmium, hexavalent chromium, mercury, copper, and zinc. In addition, when combined with specialized binders and additives, this process can stabilize low-level nuclear wastes. With modifications, the system may be applied to wastes containing between 10 to 100 percent solids.

STATUS:

The solidification and stabilization process was accepted into the SITE Demonstration Program in 1988. The process was demonstrated in March 1989 at the Portable Equipment Salvage Company site in Clackamas, Oregon. The Technology Evaluation Report (EPA/540/5-89/011a) and the Applications Analysis Report (EPA/540/A5-89/011) are available from EPA.

In addition, several full-scale remediation projects have been completed since 1977, including a 1991 high solids CHEMSET® reagent protocol designed by Chemfix to treat 30,000 cubic yards of hexavalent chromium-contaminated, high solids waste. The average chromium level after treatment was less than 0.15 milligram per liter and met toxicity characteristic leaching procedure (TCLP) criteria. The final product permeability was less than 1×10^{-6} centimeters per second (cm/sec).

DEMONSTRATION RESULTS:

The demonstration yielded the following results:

- The technology effectively reduced copper and lead concentrations in the wastes. The concentrations in the TCLP extracts from the treated wastes were 94 to 99 percent less than those from the untreated wastes. Total lead concentrations in the untreated waste approached 14 percent.

- The volume of excavated waste material increased between 20 and 50 percent after treatment.
- During the durability tests, the treated wastes showed little or no weight loss after 12 cycles of wetting and drying or freezing and thawing.
- The unconfined compressive strength of the wastes varied between 27 and 307 pounds per square inch after 28 days. Hydraulic conductivity of the treated material ranged between 1×10^{-6} cm/sec and 6.4×10^{-7} cm/sec.
- Air monitoring data suggest there was no significant volatilization of polychlorinated biphenyls during the treatment process.
- Treatment costs were approximately \$73 per ton, including mobilization, labor, reagents, and demobilization, but not disposal.

FOR FURTHER INFORMATION:

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COGNIS, INC.
(TERRAMET® Soil Remediation System)

TECHNOLOGY DESCRIPTION:

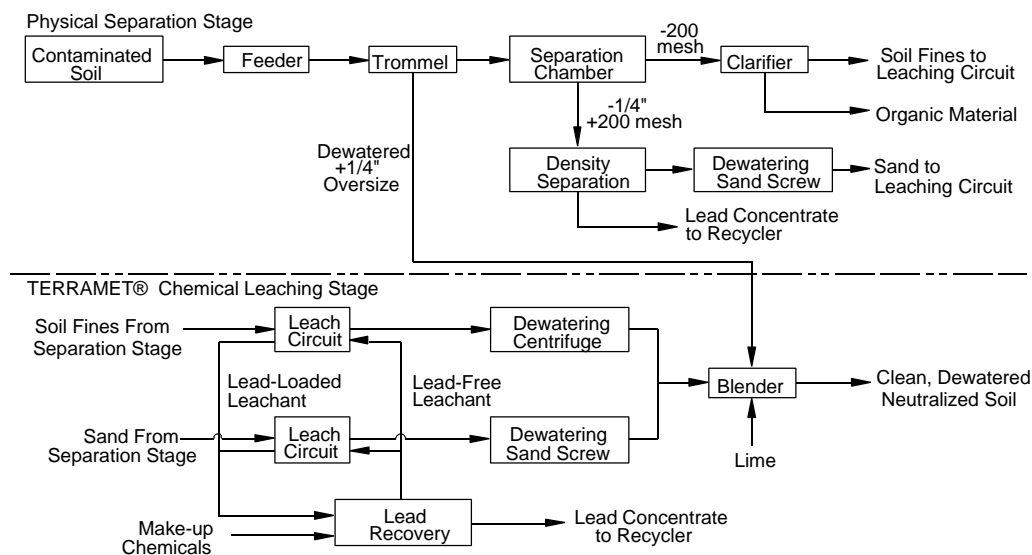
The COGNIS, Inc. (COGNIS), TERRAMET® soil remediation system leaches and recovers lead and other metals from contaminated soil, dust, sludge, or sediment. The system uses a patented aqueous leachant that is optimized through treatability tests for the soil and the target contaminant. The TERRAMET® system can treat most types of lead contamination, including metallic lead and lead salts and oxides. The lead compounds are often tightly bound by fine soil constituents such as clay, manganese and iron oxides, and humus.

The figure below illustrates the process. A pretreatment, physical separation stage may involve dry screening to remove gross oversized material. The soil can be separated into oversized (gravel), sand, and fine (silt, clay, and humus) fractions. Soil, including the oversized fraction, is first washed. Most lead contamination is typically associated with fines fraction, and this fraction is subjected to countercurrent leaching to dissolve the adsorbed lead and other heavy metal species. The sand fraction may also contain significant lead, especially if the contamination is due to particulate lead, such

as that found in battery recycling, ammunition burning, and scrap yard activities. In this case, the sand fraction is pretreated to remove dense metallic or magnetic materials before subjecting the sand fraction to countercurrent leaching. Sand and fines can be treated in separate parallel streams.

After dissolution of the lead and other heavy metal contaminants, the metal ions are recovered from the aqueous leachate by a metal recovery process such as reduction, liquid ion exchange, resin ion exchange, or precipitation. The metal recovery technique depends on the metals to be recovered and the leachant employed. In most cases, a patented reduction process is used so that the metals are recovered in a compact form suitable for recycling. After the metals are recovered, the leachant can be reused within the TERRAMET® system for continued leaching.

Important characteristics of the TERRAMET® leaching/recovery combination are as follows: (1) the leachant is tailored to the substrate and the contaminant; (2) the leachant is fully recycled within the treatment plant; (3) treated soil can be returned on site; (4) all soil fractions can be treated; (5) end products include treated soil and recycled metal; and (6) no waste is generated during



TERRAMET® Soil Remediation System

processing.

WASTE APPLICABILITY:

The COGNIS TERRAMET® soil remediation system can treat soil, sediment, and sludge contaminated by lead and other heavy metals or metal mixtures. Appropriate sites include contaminated ammunition testing areas, firing ranges, battery recycling centers, scrap yards, metal plating shops, and chemical manufacturers. Certain lead compounds, such as lead sulfide, are not amenable to treatment because of their exceedingly low solubilities. The system can be modified to leach and recover other metals, such as cadmium, zinc, copper, and mercury, from soils.

STATUS:

This technology was accepted into the SITE Emerging Technology Program in August 1992. Based on results from the Emerging Technology Program, the technology was accepted into the Demonstration Program in 1994. The demonstration took place at the Twin Cities Army Ammunition Plant (TCAAP) Site F during August 1994. The TERRAMET® system was evaluated during a full-scale remediation conducted by COGNIS at TCAAP. The full-scale system was linked with a soil washing process developed by Brice Environmental Services Corporation (BESCOP). The system treated soil at a rate of 12 to 15 tons per hour.

An Innovative Technology Evaluation Report and a Technology Capsule describing the demonstration and its results will be available in 1997.

The TERRAMET® system is no longer available through COGNIS, Inc. For further information about the system, contact the EPA Project Manager. For further information on the BESCOP soil washing process, refer to the profile in the Demonstration Program section (completed projects).

DEMONSTRATION RESULTS:

Lead levels in the feed soil ranged from 380 to 1,800 milligrams per kilogram (mg/kg). Lead levels in untreated and treated fines ranged from 210 to 780 mg/kg and from 50 to 190 mg/kg, respectively. Average removal efficiencies for lead were about 75 percent. The TERRAMET® and BESCOP processes operated smoothly at a feed rate of 12 to 15 tons per hour. Size separation using the BESCOP process proved to be effective and reduced the lead load to the TERRAMET® leaching process by 39 to 63 percent. Leaching solution was recycled, and lead concentrates were delivered to a lead smelting facility. The cost of treating contaminated soil at the TCAAP site using the COGNIS and BESCOP processes is about \$200 per ton of treated soil, based on treatment of 10,000 tons of soil. This cost includes the cost of removing ordnance from the soil.

FOR FURTHER INFORMATION:

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COMMODORE ENVIRONMENTAL SERVICES, INC. (Solvated Electron Remediation System)

TECHNOLOGY DESCRIPTION:

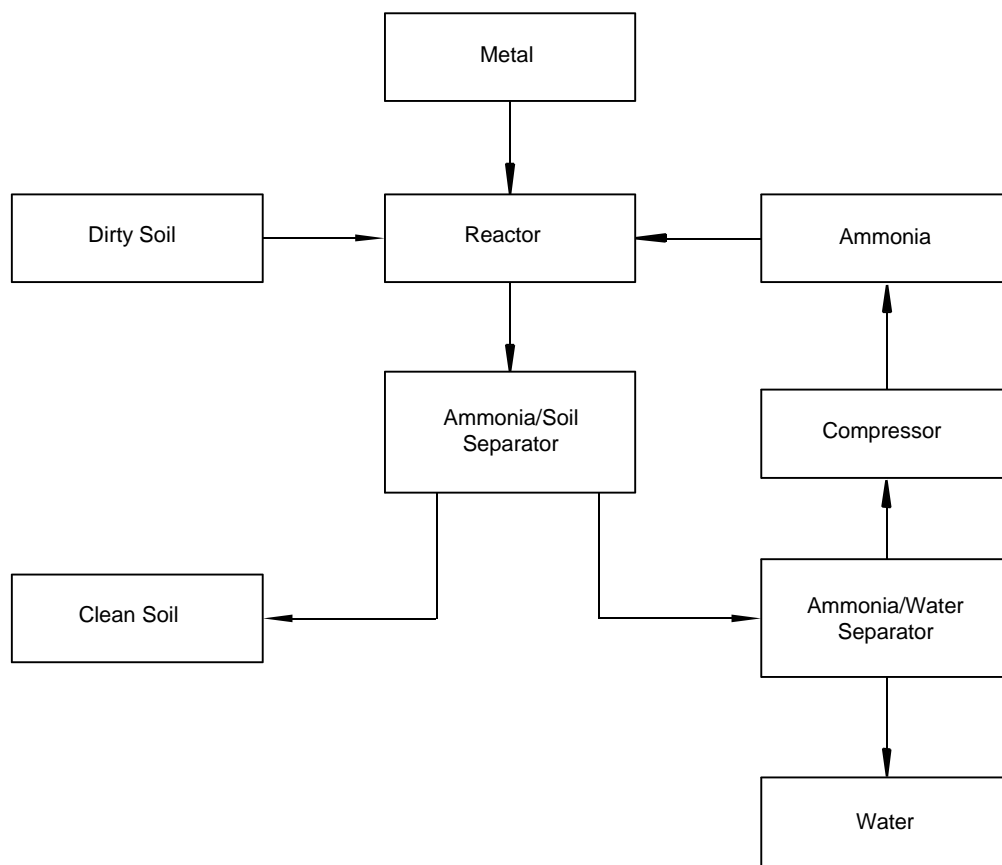
Commodore Environmental Services, Inc.'s (Commodore), solvated electron remediation system chemically transforms toxic contaminants such as polychlorinated biphenyls (PCB), pesticides, and other halogenated compounds into relatively benign substances. The solvating system uses a solution of ammonia and an "active" metal to create a powerful reducing agent that can clean up contaminated soils, sediments, and liquids.

A solvated electron solution is a liquid homogeneous mixture that produces a large supply of free electrons. It can be created by combining liquid ammonia with a metal such as sodium, calcium, lithium, or potassium. When a solvated electron solution is mixed with a contaminated material, the free electrons in the solution

chemically convert the contaminant to relatively harmless substances and salts.

The solvating system consists of components to move and recover the ammonia (such as piping, pumps, and tanks), along with reactor vessels which hold the contaminated medium and the solvating solution. The system can be transported to different field sites, but the process is performed ex situ, meaning that the contaminated medium must be introduced into the reactor vessels.

The treatment process begins by placing the contaminated medium into the reactor vessels, where the medium is then mixed with ammonia. One of the reactive metals (usually sodium) is then added to the contaminated medium-ammonia mixture, and a chemical reaction ensues. After the chemical reaction



Schematic Diagram of the Solvated Electron Remediation System

is complete (about 1 minute), the ammonia is removed to a discharge tank for reuse. The treated medium is then removed from the reactor vessels, tested for contamination, and returned to the site.

WASTE APPLICABILITY:

Commodore claims that its solvating electron remediation system can effectively decontaminate soils, sludges, sediments, oils, hand tools, and personal protective clothing. The technology chemically transforms PCBs, pesticides, and other halogenated compounds into relatively benign salts. Commodore also believes that the technology is effective in treating chemical warfare agents and radionuclides.

STATUS:

Commodore was accepted into the SITE Demonstration Program in 1995 and is also participating in the Rapid Commercialization Initiative (RCI). RCI was created by the Department of Commerce, Department of Defense, Department of Energy, and EPA to assist in the integration of innovative technologies into the marketplace.

Commodore demonstrated the solvating system at the Construction Battalion Supply Center in Port Hueneme, California in September 1996. The demonstration was designed to evaluate the system's performance capability, costs, and design parameters. Results from the demonstration will be presented in an Innovative Technology Evaluation Report, which will be available in 1997.

FOR FURTHER INFORMATION:

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DEHYDRO-TECH CORPORATION

(Carver-Greenfield Process® for Solvent Extraction of Wet, Oily Wastes)

TECHNOLOGY DESCRIPTION:

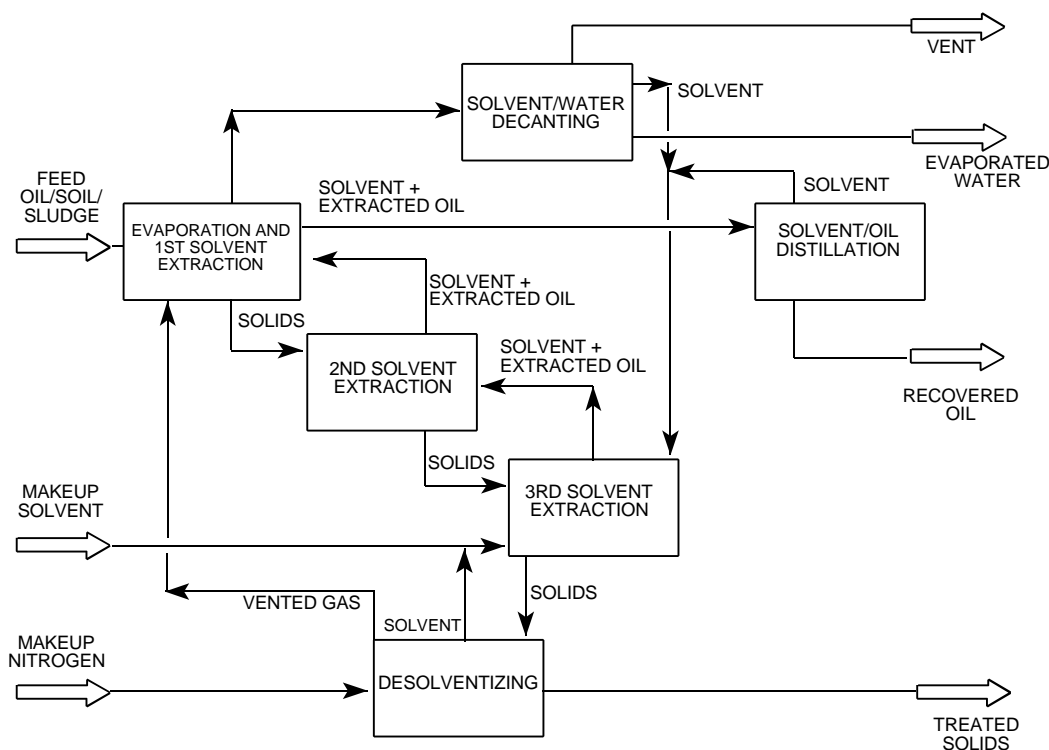
The Carver-Greenfield Process® (C-G Process™) combines dehydration and solvent extraction technologies to separate wet, oily wastes into their constituent solid, water, and oil phases (see figure below).

Waste is first mixed with a low-cost hydrocarbon solvent. The resultant slurry mixture is fed to an evaporator system that vaporizes water and initiates solvent extraction of the indigenous oil. Depending on the water content of the feed, single-effect or energy-saving multi-effect evaporators may be used. Next, the slurry of dried solids is treated in a multistage solvent extraction unit, where solids contact recycled solvent until the target amount of indigenous oil is removed.

Finally, solids are centrifuged away from the solvent, followed by "desolventizing," an operation that evaporates residual solvent. The final solids product typically contains less than 2 percent water and less than 1 percent solvent. The spent solvent, which contains the extracted indigenous oil, is distilled to separate the solvent for reuse, and the oil for recovery or disposal.

The C-G Process yields (1) a clean, dry solid; (2) a water product virtually free of solids, indigenous oil, and solvent; and (3) the extracted indigenous oil, which contains the hazardous hydrocarbon-soluble feed components.

The C-G Process combination of dehydration and solvent extraction has the following advantages: (1) any emulsions initially present are broken and



Carver-Greenfield Process® Schematic Diagram

potential emulsion formation is prevented; (2) solvent extraction is more efficient because water is not present; and (3) the dry solids product is stabilized more readily if required (for example, if metals contamination is a concern).

WASTE APPLICABILITY:

The C-G Process can treat sludges, soils, sediments, and other water-bearing wastes containing hydrocarbon-soluble hazardous compounds, including polychlorinated biphenyls, polynuclear aromatic hydrocarbons, and dioxins. The process has been commercially applied to municipal wastewater sludge, paper mill sludge, rendering waste, pharmaceutical plant sludge, and other wastes.

STATUS:

The C-G Process was accepted into the SITE program in 1990. The pilot-scale SITE demonstration of this technology was completed in August 1991 at EPA's research facility in Edison, New Jersey. Spent petroleum drilling fluids from the PAB oil site in Abbeville, Louisiana were used as process feed. The Applications Analysis Report (EPA/540/AR-92/002), Technology Demonstration Summary (EPA/540/SR-92/002), and Technology Evaluation Report (EPA/540/R-92/002) are available from EPA.

DEMONSTRATION RESULTS:

The SITE demonstration of the C-G Process yielded the following results:

- The process successfully separated the petroleum-contaminated sludge into its solid, indigenous oil, and water phases. No detectable levels of indigenous total petroleum hydrocarbons were present in the final solid product.

- The final solid product was a dry powder similar to bentonite. A food-grade solvent comprised the bulk of the residual hydrocarbons in the solid.
- Values for all metals and organics were well below the Resource Conservation and Recovery Act toxicity characteristic leaching procedure limits for characteristic hazardous wastes.
- The resulting water product required treatment due to the presence of small amounts of light organics and solvent. Normally, it may be disposed of at a local publicly owned treatment works.
- A full-scale C-G Process can treat drilling fluid wastes at technology-specific costs of \$100 to \$220 per ton of wet feed, exclusive of disposal costs for the residuals. Site-specific costs, which include the cost of residual disposal, depend on site characteristics and treatment objectives.

FOR FURTHER INFORMATION:

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E.I. DUPONT DE NEMOURS AND COMPANY, and OBERLIN FILTER COMPANY (Membrane Microfiltration)

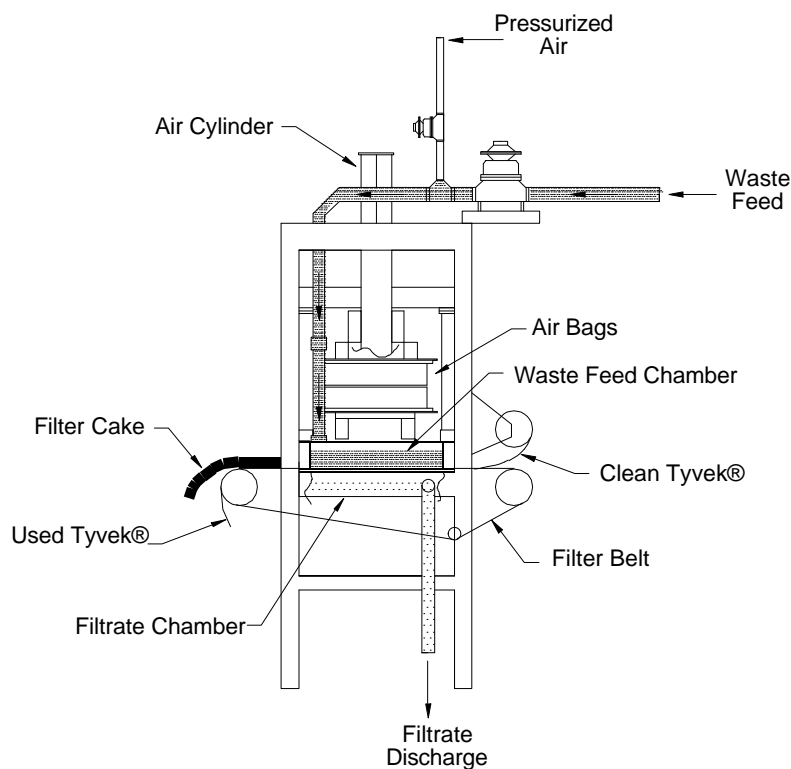
TECHNOLOGY DESCRIPTION:

This membrane microfiltration system is designed to remove solid particles from liquid wastes, forming filter cakes typically ranging from 40 to 60 percent solids. The system can be manufactured as an enclosed unit, requires little or no attention during operation, is mobile, and can be trailer-mounted.

The membrane microfiltration system uses an automatic pressure filter (developed by Oberlin Filter Company), combined with a special Tyvek® filter material (Tyvek® T-980) made of spun-bonded olefin (invented by E.I. DuPont de Nemours and Company) (see figure below). The filter material is a thin, durable plastic fabric with tiny openings about 1 ten-millionth of a meter in diameter. These openings allow water or other liquids and solid particles smaller than the openings to flow through. Solids in the liquid stream that are too large to pass through the openings

accumulate on the filter and can be easily collected for disposal.

The automatic pressure filter has two chambers: an upper chamber for feeding waste through the filter, and a lower chamber for collecting the filtered liquid (filtrate). At the start of a filter cycle, the upper chamber is lowered to form a liquid-tight seal against the filter. The waste feed is then pumped into the upper chamber and through the filter. Filtered solids accumulate on the Tyvek® surface, forming a filter cake, while filtrate collects in the lower chamber. Following filtration, air is fed into the upper chamber at a pressure of about 45 pounds per square inch. Air removes any liquid remaining in the upper chamber and further dries the filter cake. When the filter cake is dry, the upper chamber is lifted, and the filter cake is automatically discharged. Clean filter material is then drawn from a roll into the system for the next cycle. Both the filter cake and the filtrate can be collected and



Membrane Microfiltration System

treated further before disposal, if necessary.

WASTE APPLICABILITY:

This membrane microfiltration system may be applied to (1) hazardous waste suspensions, particularly liquid heavy metal- and cyanide bearing wastes (such as electroplating rinsewaters), (2) groundwater contaminated with heavy metals, (3) constituents in landfill leachate, and (4) process wastewaters containing uranium. The technology is best suited for treating wastes with solids concentrations of less than 5,000 parts per million; otherwise, the cake capacity and handling become limiting factors. The system can treat any type of solids, including inorganics, organics, and oily wastes, with a wide variety of particle sizes. Moreover, because the system is enclosed, it can treat liquid wastes that contain volatile organics.

STATUS:

The membrane microfiltration system, accepted into the SITE Program in 1988, was demonstrated at the Palmerton Zinc Superfund site in Palmerton, Pennsylvania. The demonstration was conducted over a 4-week period in April and May 1990. Groundwater from the shallow aquifer at the site was contaminated with dissolved heavy metals, including cadmium, lead, and zinc. This contaminated groundwater served as the feed waste for the demonstration. The system treated waste at a rate of about 1 to 2 gallons per minute.

The Applications Analysis Report (EPA/540/A5-90/007), the Technology Evaluation Report (EPA/540/5-90/007), and a videotape of the demonstration are available from EPA.

Since 1991, about 12 commercial installations of the technology have been operational.

DEMONSTRATION RESULTS:

During the demonstration at the Palmerton Zinc Superfund site, the membrane microfiltration system achieved the following results:

- Removal efficiencies for zinc and total suspended solids ranged from 99.75 to 99.99 percent (averaging 99.95 percent).
- Solids in the filter cake ranged from 30.5 to 47.1 percent.
- Dry filter cake in all test runs passed the Resource Conservation and Recovery Act paint filter liquids test.
- Filtrate met the applicable National Pollutant Discharge Elimination System standards for cadmium, lead, zinc, and total suspended solids.
- A composite filter cake sample passed the extraction procedure toxicity and toxicity characteristic leaching procedure tests for metals.

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DYNAPHORE, INC. (FORAGER® Sponge)

TECHNOLOGY DESCRIPTION:

The FORAGER® Sponge (Sponge) is an open-celled cellulose sponge containing a polymer with selective affinity for dissolved heavy metals in both cationic and anionic states. The polymer contains iminodiacetic acid groups which enter into chelation bonding with transition-group heavy metal cations. The polymer's affinity for particular cations is influenced by solution parameters such as pH, temperature, and total ionic content. In general, the following affinity sequence for several representative ions prevails:

$Cd^{++} > Cu^{++} > Hg^{++} > Pb^{++} > Au^{+++} > Zn^{++} > Fe^{+++} > Ni^{++} > Co^{++} > Al^{+++} > Ca^{++} > Mg^{++} > Na^{+}$

During absorption, a cation is displaced from the polymer. The displaced cation may be H^{+} or a cation below the absorbed cation in the affinity sequence.

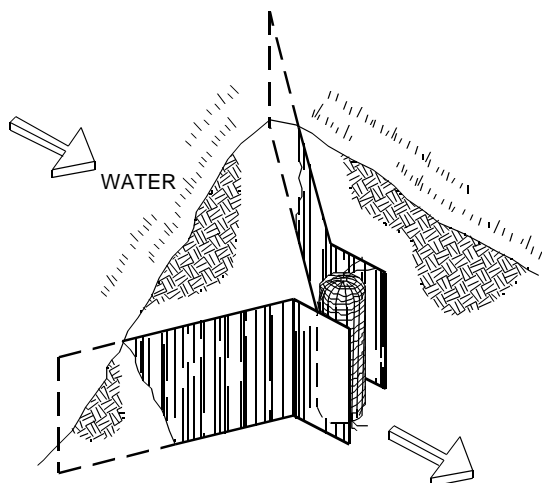
The polymer also contains tertiary amine salt groups which exhibit selective bonding for anion species such as the following:

CrO_4^{-2} , AsO_4^{-3} , $Au(CN)_2^{-}$, SeO_4^{-2} , $HgCl_2^{-}$, $Ag(S_2O_3)^{-3}$, SiO_3^{-2} , UO_4^{-2}

The absorption of certain anion species can be enhanced by preabsorption of a cation that ordinarily reacts with a sought anion to produce a highly insoluble compound. For example, a Sponge presaturated with Fe^{+3} strongly absorbs arsenate anion because ferric arsenate is highly insoluble.

The removal efficiency for transition-group heavy metals is about 90 percent at a flow rate of 0.1 bed volume per minute. The Sponge's highly porous nature speeds diffusional effects, promoting high rates of ion absorption. The Sponge can be used in columns, fishnet-type enclosures, or rotating drums. When used in a column, flow rates of three bed volumes per minute can be obtained at hydrostatic pressures only 2 feet above the bed and without additional pressurization. Therefore, Sponge-packed columns are suitable for unattended field use.

Absorbed ions can be eluted from the Sponge using techniques typically employed to regenerate ion-exchange resins and activated carbon. Following elution, the Sponge can be used in the next absorption cycle. The number of useful cycles depends on the nature of the absorbed ions and the elution technique used. Alternatively, the metal-saturated Sponge can be incinerated. In some instances, the Sponge may be dried and reduced in volume to facilitate disposal.



Fishnet Bags Placed Vertically in a Well

A trailer-mounted pump-and-treat apparatus can handle up to 10 gallons per minute with low pumping pressures of 4 to 10 pounds per square inch. The apparatus employs four or six Plexiglas columns, connected in series, with valving to expedite regeneration and staging. Each column accommodates a fishnet container of Sponge in the form of half-inch cubes. Groundwater can be remediated in situ using elongated fishnet bags that confine the Sponge. The bags are placed vertically in wells, as shown in the figure to the left, or placed horizontally in trenches, as shown in the figure on the next page. Alternatively, the groundwater can be treated aboveground in a packed column configuration.

WASTE APPLICABILITY:

The Sponge can scavenge metals in concentration levels of parts per million and parts per billion from industrial discharges, municipal sewage, process streams, and acid mine drainage. The Sponge is particularly useful when treating water with low contaminant levels, especially in polishing or end-of-pipe treatments. Because of the low capital investment required, the Sponge is well-suited for use in short-term remediation projects and for sporadic flows conditions.

STATUS:

This technology was accepted into the SITE Demonstration Program in June 1991. The Sponge was demonstrated in April 1994 at the National Lead Industry site in Pedricktown, New Jersey. The Demonstration Bulletin (EPA/540/MR-94/522), Technology Capsule (EPA/540/R-94/522a), and Innovative Technology Evaluation Report (EPA/540/R-94/522) are available from EPA.

The Sponge has also effectively removed trace heavy metals from acid mine drainage at three locations in Colorado. In bench-scale tests, the Sponge reduced mercury, lead, nickel, cadmium, and chromium in groundwater from various Superfund locations to below detectable levels. The Sponge was also demonstrated in a field-scale installation at a photoprocessing operation. The process reduced chromate and silver by 75 percent at a cost of \$1,100 per month. In bench-scale tests, the Sponge

has removed lead, mercury, and copper from pourable sludges such as simulated municipal sewage, and from soils slurried with water.

DEMONSTRATION RESULTS:

Treatment performance from the SITE demonstration was as follows:

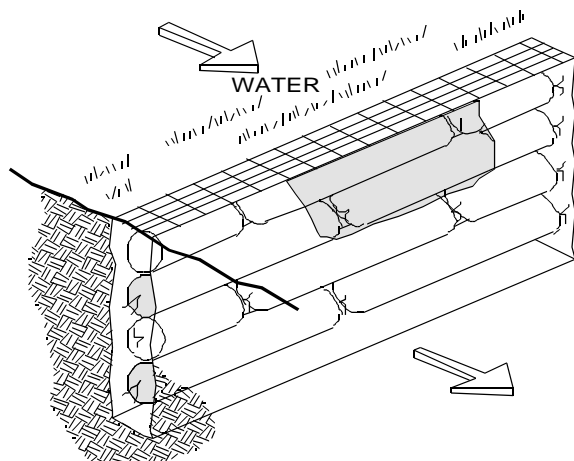
Analyte	Average Influence Concentration ($\mu\text{g/L}$)	Percent Removal
Cadmium	537	90
Copper	917	97
Lead	578	97
Chromium ^{III}	426	32

In 1996, the Sponge, configured in a column, was employed in a pump-and-treat remediation of 360,000 gallons of water that had accumulated as a result of a fuel handling operation. The water, containing 0.2 parts per million (ppm) arsenic, was treated at 12 gallons per minute (0.1 bed volume per minute) to produce an effluent having a nondetect level of arsenic.

FOR FURTHER INFORMATION:

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Fishnet Bags Placed Horizontally in a Trench

ECOVA CORPORATION (Bioslurry Reactor)

TECHNOLOGY DESCRIPTION:

The ECOVA Corporation (ECOVA) slurry-phase bioremediation (bioslurry) technology aerobically biodegrades creosote-contaminated materials. The technology uses batch and continuous flow bioreactors to process polynuclear aromatic hydrocarbon (PAH)-contaminated soils, sediments, and sludges. The bioreactors are supplemented with oxygen, nutrients, and a specific inoculum of enriched indigenous microorganisms to enhance the degradation process.

Because site-specific environments influence biological treatment, all chemical, physical, and microbial factors are designed into the treatment process. The ultimate goal is to convert organic wastes into relatively harmless by-products of microbial metabolism, such as carbon dioxide, water, and inorganic salts. Biological reaction rates are accelerated in a slurry system because of the

increased contact efficiency between contaminants and microorganisms. The photograph below shows the bioslurry reactor.

WASTE APPLICABILITY:

The bioslurry reactor is designed to treat highly contaminated creosote wastes. It can also treat other concentrated contaminants that can be aerobically biodegraded, such as petroleum wastes. The bioslurry reactor system must be engineered to maintain parameters such as pH, temperature, and dissolved oxygen within ranges conducive to the desired microbial activity.

STATUS:

This technology was accepted into the SITE Demonstration Program in spring 1991. From May through September 1991, EPA conducted a SITE demonstration using six bioslurry reactors at EPA's



Bioslurry Reactor

Test and Evaluation Facility in Cincinnati, Ohio.

ECOVA conducted bench- and pilot-scale studies to evaluate bioremediation of PAHs in creosote-contaminated soil from the Burlington Northern Superfund site in Brainerd, Minnesota. Bench-scale studies were conducted before pilot-scale evaluations to determine optimal treatment protocols. EIMCO Biolift™ slurry reactors were used for the pilot-scale processing. Data from the optimized pilot-scale program were used to establish treatment standards for K001 wastes as part of EPA's Best Demonstrated Available Technology program.

This technology is no longer available through ECOVA. However, the technology is being implemented by Walsh Environmental Scientists & Engineers. For further information on the technology, contact either the EPA Project Manager or the technology developer contact.

DEMONSTRATION RESULTS:

Results from the SITE demonstration indicated that slurry-phase biological treatment significantly improved biodegradation rates of carcinogenic 4- to 6-ring PAHs. The pilot-scale bioslurry reactor reduced 82 ± 15 percent of the total soil-bound PAHs in the first week. After 14 days, total PAHs had been biodegraded by 96 ± 2 percent. An overall reduction of 97 ± 2 percent was observed over a 12-week treatment period, indicating that almost all biodegradation occurred within the first 2 weeks of treatment. Carcinogenic PAHs were biodegraded by 90 ± 3.2 percent to 501 ± 103 milligrams per kilogram (mg/kg) from levels of $5,081 \pm 1,530$ mg/kg.

FOR FURTHER INFORMATION:

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ELI ECO LOGIC INTERNATIONAL INC.
(Gas-Phase Chemical Reduction Process)

TECHNOLOGY DESCRIPTION:

The patented ELI Eco Logic International Inc. (Eco Logic), process (see photograph below) uses a gas-phase reduction reaction of hydrogen with organic and chlorinated organic compounds at elevated temperatures to produce a hydrocarbon-rich gas product. During the SITE demonstration, soils were pretreated within Eco Logic's thermal desorption unit (TDU), which was operated in conjunction with the reduction reactor. For further information on Eco Logic's TDU, see the profile in the Demonstration Program section (completed projects).

The gas-phase reduction reaction takes place within a specially designed reactor at ambient pressure. Separate nozzles inject gaseous atomized waste, steam, and hydrogen into the reactor. As the mixture swirls down between the outer reactor wall and a central ceramic tube, it passes a series of electric glo-bar heaters, raising the temperature to 850 °C. The reduction reaction takes place as the

gases enter the ceramic tube through inlets at the bottom of the tube and travel up toward the scrubber. The scrubber removes hydrogen chloride, heat, water, and particulate matter. If necessary, scrubber liquid may be recycled through the system for additional treatment.

For waste with a low organic content, the majority of the hydrogen-rich gas recirculates to the reactor; the remainder can be used as a supplementary fuel for a propane-fired boiler that produces steam. Processing waste with a high organic content produces excess gas product, which can be compressed and stored for later analysis and reuse as supplementary fuel.

The unit is mounted on two standard, drop-deck, highway trailers. A computerized process control system allows the operator to monitor process variables such as temperature, pressure, hydrogen content, and oxygen levels. In addition, an on-line mass spectrometer is used to continually monitor selected organic compounds.



Gas-Phase Chemical Reduction Process

WASTE APPLICABILITY:

The Eco Logic process is designed to treat aqueous and oily waste streams and soil or sludge contaminated with hazardous organic waste such as polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons, chlorinated dioxins and dibenzofurans, chlorinated solvents, chlorobenzenes, and chlorophenols. Wastes with high water content are easily handled by the process since water is a good source of hydrogen.

STATUS:

In October and November 1992, the Eco Logic process was demonstrated at the Middleground Landfill in Bay City, Michigan, under a Toxic Substances Control Act research and development permit. The demonstration was conducted in cooperation with Environment Canada and the Ontario Ministry of the Environment. The test was performed using PCB-contaminated wastewater, waste oil, and soil from the site. The Demonstration Bulletin (EPA/540/MR-93/522) and the Applications Analysis Report (EPA/540/AR-93/522) are available from EPA.

Since the SITE demonstration, Eco Logic has developed a commercial-scale system (the SE25) which is designed to treat 100 to 300 tons per day of contaminated soil or sediment and 20 tons per day of PCB liquid. The SE25 combines the reduction reactor, which treats PCB oils and aqueous wastes, with a redesigned TDU, which treats contaminated soils and sediments and an SBV for treating bulk solids such as electrical equipment, drums, and personal protective equipment.

Two commercial-scale SE25 treatment units are currently in operation; one in Perth, Western Australia, and the other at a General Motors of Canada Ltd (GMCL) facility in Ontario. Both are currently treating a variety of waste matrices, including DDT residues and PCBs in soil, oils, electrical equipment, concrete, and other solids. Following the GMCL project, the unit will be relocated to Toronto, Ontario where General Electric (GE) and Eco Logic have a contract to destroy PCB-impacted materials stored

aboveground at GE's Lansdowne and Davenport facility. Eco Logic has also been awarded a contract through the Department of Energy's Morgantown Energy Technology Center for treatment of hazardous wastes, radioactive mixed low-level wastes, and energetics-explosives.

DEMONSTRATION RESULTS:

During the demonstration, two separate waste feed conditions were used: (1) wastewater containing an average PCB concentration of 4,600 parts per million, and (2) waste oil containing an average PCB concentration of 24.5 percent. Both feeds were tested in triplicate. The demonstration of the Eco Logic process yielded the following results:

- At least 99.99 percent destruction and removal efficiency for PCBs during all runs
- A 99.99 percent destruction efficiency for perchloroethylene, a tracer compound, during all runs
- Net destruction of trace feedstock dioxin and furan compounds during all runs

FOR FURTHER INFORMATION:

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ELI ECO LOGIC INTERNATIONAL INC. (Thermal Desorption Unit)

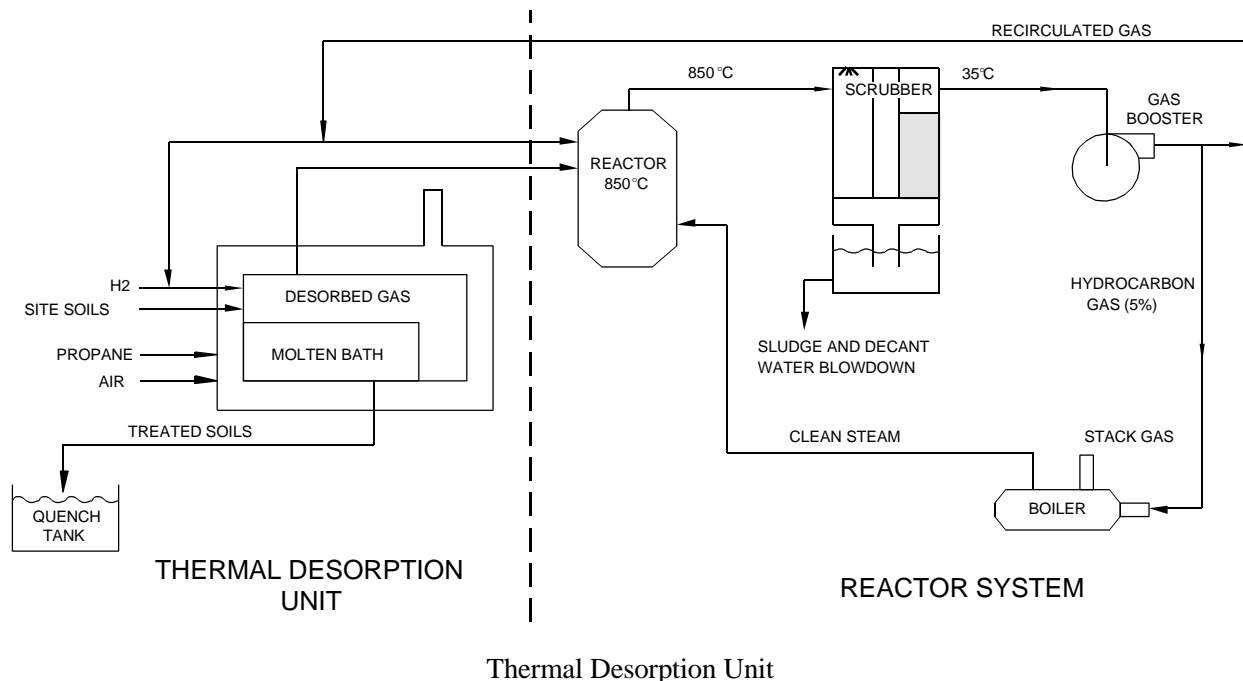
TECHNOLOGY DESCRIPTION:

The ELI Eco Logic International Inc. (Eco Logic), thermal desorption unit (TDU) is specially designed for use with Eco Logic's gas-phase chemical reduction process. The TDU, shown in the figure below, consists of an externally heated bath of molten tin metal (heated with propane) in a hydrogen gas atmosphere. Tin is used for several reasons: tin and hydrogen are nonreactive; tin's density allows soils to float on the molten bath; molten tin is a good fluid for heat transfer; tin is nontoxic in soil; and tin is used as a bath medium in the manufacture of plate glass.

Contaminated soil is conveyed into the TDU feed hopper, where an auger feeds the soil into the TDU. A screw feeder provides a gas seal between the outside air and the hydrogen atmosphere inside the TDU. The auger's variable speed drive provides feed rate control. Soil inside the TDU floats on top of the molten tin and is heated to 600 °C vaporizing the water and organic material. Decontaminated soil is removed from the tin bath into a water-filled quench tank. The water in the

quench tank provides a gas seal between the TDU's hydrogen atmosphere and the outside air. A scraper mechanism removes decontaminated soil from the quench tank into drums.

After desorption from the soil, the organic contaminants are carried from the TDU to Eco Logic's proprietary gas-phase reduction reactor. In the reactor, the organic contaminants undergo gas-phase chemical reduction reactions with hydrogen at elevated temperatures and ambient pressure. This reaction converts organic and chlorinated organic contaminants into a hydrocarbon-rich gas product. After passing through a scrubber, the gas product's primary components are hydrogen, nitrogen, methane, carbon monoxide, water vapor, and other lighter hydrocarbons. Most of this gas product recirculates into the process, while excess gas can be compressed for later analysis and reuse as supplemental fuel. For further information on the Eco Logic gas-phase chemical reduction process, see the profile in the Demonstration Program section (completed projects).



WASTE APPLICABILITY:

The Eco Logic TDU, when used with the gas-phase chemical reduction reactor, is designed to desorb soils and sludges contaminated with hazardous organic contaminants such as polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons, chlorinated dioxins and dibenzofurans, chlorinated solvents, chlorobenzenes, and chlorophenols. The combined technologies are suited for wastes with high water content since water is a good source of hydrogen.

STATUS:

In October and November 1992, the Eco Logic process, including the TDU, was demonstrated at the Middleground Landfill in Bay City, Michigan, under a Toxic Substances Control Act research and development permit. The Demonstration Bulletin (EPA/540/MR-94/504) and the Applications Analysis Report (EPA/540/AR-94/504) are available from EPA.

Further research and development since the demonstration has focused on optimizing the process for commercial operations and improving the design of the soil and sediment processing unit. According to Eco Logic, the TDU design currently in commercial operation has achieved excellent results, with contaminants in soils and sediments desorbed from high parts per million (ppm) levels to low parts per billion levels.

Two commercial-scale SE25 treatment units are currently in operation; one in Perth, Western Australia, and the other at a General Motors of Canada Ltd (GMCL) facility in Ontario. Both are currently treating a variety of waste matrices including DDT residues and PCBs in soils, oils, electrical equipment, concrete, and other solids. Following the GMCL project, the unit will be relocated to Toronto, Ontario where General Electric (GE) and Eco Logic have a contract to destroy PCB-impacted materials stored aboveground at GE's Lansdowne and Davenport facility.

Also, Eco Logic has teamed with Westinghouse Electric to treat chemical warfare agents using the process. Eco Logic has been awarded a contract through the Department of Energy's Morgantown Energy Technology Center for treatment of hazardous wastes, radioactive mixed low-level wastes, and energetics-explosives.

DEMONSTRATION RESULTS:

During the demonstration in Bay City, Michigan, the Eco Logic TDU achieved the following:

- Desorption efficiencies for PCBs from the soil of 93.5 percent in run one and 98.8 percent in run two
- Desorption efficiency for hexachlorobenzene (a tracer compound) from the soil of 72.13 percent in run one and 99.99 percent in run two
- PCB destruction and removal efficiencies of 99.99 percent for the combined TDU and reduction reactor

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ENVIROMETAL TECHNOLOGIES INC.

(In Situ and Ex Situ Metal-Enhanced Abiotic Degradation of Dissolved Halogenated Organic Compounds in Groundwater)

TECHNOLOGY DESCRIPTION:

This remedial technology, developed by the University of Waterloo and EnviroMetal Technologies Inc., degrades dissolved halogenated organic compounds in groundwater with an in situ permeable wall containing reactive metal (usually iron) (see photograph below). The technology may also be used in an aboveground reactor for ex situ treatment.

The technology employs an electrochemical process. Contaminated groundwater passes through the specially prepared granular reactive iron, which oxidizes, inducing reductive dehalogenation of contaminants. Halogenated organics are degraded to nonhazardous substances, preventing contaminants from migrating further downstream. Observed degradation rates are several times higher than those reported for natural abiotic degradation processes.

In most in situ applications of this technology, groundwater moves naturally through the permeable subsurface wall or is directed by flanking impermeable sections such as sheet piles or slurry walls. This passive remediation method is a cost-effective alternative to conventional pump-and-treat methods. Aboveground reactor vessels employing this technology may replace or add to treatment units in conventional pump-and-treat systems.

Process residuals may include dissolved ethane, ethene, methane, hydrogen gas, chloride, and ferrous iron. Because contaminants are degraded to nonhazardous substances and not transferred to another medium, this process eliminates the need for waste treatment or disposal.

WASTE APPLICABILITY:

The process was developed to treat dissolved halogenated organic compounds in groundwater. The technology has degraded a wide variety of chlorinated alkanes and alkenes, including



Installation of Pilot-Scale In Situ Treatment System
at an Industrial Facility in Northeast United States

trichloroethene (TCE), tetrachloroethene (PCE), vinyl chloride, 1,1,1-trichloroethane, and 1,2-dichloroethene (DCE). The technology also degrades other organic contaminants, including Freon-113, ethylene dibromide, certain nitroaromatics, and N-nitrosodimethylamine.

STATUS:

This technology was accepted into the SITE Demonstration Program in spring 1993. A pilot-scale demonstration of the aboveground reactor (ex situ) technology took place from November 1994 to February 1995 at an industrial facility in New Jersey. Groundwater at the facility contained dissolved TCE and PCE.

A second SITE demonstration was performed in New York from May through December 1995. A pilot-scale in situ permeable wall was installed in a shallow sand and gravel aquifer containing TCE, DCE, vinyl chloride, and 1,1,1-trichloroethane. This project may eventually be expanded to full-scale.

A successful permeable in situ wall was installed at the Canadian Forces Base Borden test site in June 1991. The technology removed about 90 percent of the TCE and PCE from groundwater passing through the reactive iron wall. The wall has performed consistently for 5 years. More than 250 sites have been identified where the technology could be applied. Over 50 successful bench-scale feasibility tests have been completed using groundwater from industrial and government facilities in the United States and Canada.

The first full-scale, in situ installation of this technology was completed at an industrial facility in California in December 1994. Since that time, five additional full-scale in situ systems and three pilot-scale systems have been installed in locations including Colorado, Kansas, North Carolina and Belfast, Northern Ireland. Several more are planned for 1997. Aboveground treatment systems have been proposed at sites in Maryland and Germany.

DEMONSTRATION RESULTS:

During the New Jersey (ex situ) demonstration, about 60,833 gallons of groundwater was treated during 13 weeks of sampling. Conversion efficiency of PCE during the demonstration period exceeded 99.9 percent. Vinyl chloride and cis-1,2-dichloroethene occasionally exceeded the New Jersey Department of Environmental Protection limits. This exceedance may have been caused by a reduction in the iron's reactive capacity due to precipitate formation. Complete demonstration results will be published in the Technology Capsule and Innovative Technology Evaluation Report (ITER), which will be available in 1997.

For the New York (in situ) demonstration, preliminary data indicate a significant reduction in all critical contaminants present, and no apparent decrease in removal efficiency over the seven month demonstration period. Results of the in situ demonstration of the process will be published in an ITER that will be available in 1997.

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EPOC WATER, INC.
(Precipitation, Microfiltration, and Sludge Dewatering)

TECHNOLOGY DESCRIPTION:

The precipitation, microfiltration, and sludge dewatering treatment uses a combination of processes to treat a variety of wastes. In the first step of the process, heavy metals are chemically precipitated. Precipitates and all particles larger than 0.2 micron are filtered through a unique tubular textile crossflow microfilter (EXXFLOW). The concentrate stream is then dewatered in a filter press of the same material.

EXXFLOW microfilter modules are fabricated from a proprietary tubular woven polyester. Wastes pumped into the polyester tubes form a dynamic membrane, which produces a high quality filtrate and removes all particle sizes larger than 0.2 micron. The flow velocity continually maintains the membrane, maximizing treatment efficiency.

Metals are removed through precipitation by adjusting the pH in the EXXFLOW feed tank. Metal hydroxides or oxides form a dynamic

membrane with any other suspended solids. The EXXFLOW concentrate stream, which contains up to 5 percent solids, is then dewatered. A semidry cake, up to 0.25 inch thick, is formed inside the tubular filter. When the discharge valve is opened, rollers on the outside of the tubes move to form a venturi within the tubes. The venturi creates an area of high velocity within the tubes, which aggressively cleans the cloth and discharges the cake in chip form onto a wedge wire screen. Discharge water is recycled to the feed tank. Filter cakes are typically 40 to 60 percent solids by weight.

Constituents other than metals can be removed using seeded slurry methods in EXXFLOW. Hardness can be removed by using lime. Oil and grease can be removed by adding adsorbents. Nonvolatile organics and solvents can be removed using adsorbents, activated carbon, or powdered ion-exchange resins.

The EXXFLOW demonstration unit (see photograph below) is transportable and is



EXXFLOW Demonstration Unit

mounted on skids. The unit is designed to process approximately 30 pounds of solids per hour and 10 gallons of wastewater per minute.

WASTE APPLICABILITY:

When flocculation and precipitation techniques are used at close to stoichiometric dosing rates, the EXXFLOW technology removes mixed metals, oil and grease, and suspended solids sized at 0.10 micron.

When the EXXFLOW technology operates with finely divided adsorbent powders, it removes contaminants such as isophthalic acid, acetic acid, methyl ethyl ketone, fluorides, and phosphates from effluents generated by semiconductor manufacture. Treated effluents can then be reclaimed for reuse.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1989. Bench-scale tests were conducted in 1990. The SITE demonstration was conducted during May and June 1992 on highly acidic mine drainage from the Old Number 8 mine seep at the Iron Mountain Superfund site in Redding, California. The Demonstration Bulletin (EPA/540/MR-93/513) and the Applications Analysis Report (EPA/540/AR-93/513) are available from EPA.

This technology was commercialized in 1988. Treatment systems have since been installed at over 45 sites worldwide. System capacities range from 1 gallon per minute to over 2 million gallons per day.

DEMONSTRATION RESULTS:

During the SITE Demonstration, developer claims for metal removal efficiencies on acid mine drainage, when neutralizing with sodium hydroxide (NaOH) and calcium hydroxide [Ca(OH)₂], were generally met or exceeded except for aluminum. This was most likely due to excessive alkalinity (high pH) produced by the added NaOH and Ca(OH)₂, which redissolved the aluminum. The claims for all metals, including aluminum, were exceeded when magnesium oxide (MgO) was used as the neutralizing agent. In most cases, no detectable concentrations of heavy metals were present in the permeate samples.

Filter cake produced from the demonstration test contained approximately 12 percent, 31 percent, and 30 percent solids when NaOH, Ca(OH)₂, and MgO, respectively, were used as the treatment chemicals. Toxicity characteristic leaching procedure (TCLP) tests performed on the filter cake showed that leachable levels of TCLP metals were below regulatory limits for each treatment chemical tested.

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FILTER FLOW TECHNOLOGY, INC.
(Colloid Polishing Filter Method®)

TECHNOLOGY DESCRIPTION:

The Colloid Polishing Filter Method® (CPFM®) uses inorganic, oxide-based sorption particles (FF-1000®) and optimized fluidics control to remove ionic, colloidal heavy metals and nontritium radionuclides from water. Beta- and alpha-emitting radionuclides can be treated selectively by modifying the bed formulation. The methodology efficiently removes inorganics from groundwater, pond water, or wastewater based on sorption, chemical and physical properties of the pollutant species, and filtration. The CPFM® is also an efficient heavy metals and radionuclide polishing filter for groundwater and wastewater. Excess solids and total dissolved solids must be removed first, since they overload the beds, resulting in frequent bed backwashing and regeneration cycles and shorter bed lifetimes.

Three different types of CPFM® equipment have been designed and successfully tested: (1) vertical plate design beds with FF-1000® sorption bed particles packaged in polymesh bags or filter packs for field applications; (2) small, filter-housing units for processing less than 1,000 gallons of contaminated water; and (3) deep-bed, epoxy-coated, stainless steel and carbon steel tanks equipped with special fluidics controls and bed sluicing ports for continuous processing. The photograph below shows a mobile CPFM® unit.

WASTE APPLICABILITY:

The CPFM® efficiently removes heavy metals and nontritium radionuclides from water to parts per million or parts per billion levels. This simple methodology can be used separately to treat water



Mobile CPFM® Unit, Including Mixing Tanks,
Pumps, Filter Apparatus, and Other Equipment

with low total suspended solids; in a treatment train downstream from other technologies such as soil washing or organic oxidation; or as a conventional wastewater treatment that uses flocculation and solids removal.

The CPFM®'s major advantages are its high performance; alpha and beta emitter efficiency; and its application to monovalent, divalent, multivalent, and high valence forms existing as colloids, and ionic, chelated, and complexed forms. The same equipment can treat water at different sites, but the preconditioning chemistry and pH must be optimized for each site through bench-scale and field testing.

STATUS:

This technology was accepted into the SITE Demonstration Program in July 1991. EPA and the U.S. Department of Energy (DOE) cosponsored the technology evaluation. The SITE demonstration occurred in September 1993 at DOE's Rocky Flats Plant (RFP) in Denver, Colorado. The Demonstration Bulletin (EPA/540/MR-94/501), Technology Capsule (EPA/540/R-94/501a), and Innovative Technology Evaluation Report (EPA/540/R-94/501) are available from EPA.

The CPFM has been demonstrated independent of the SITE Program at two locations at DOE's Hanford facility, where it removed Strontium-90, Cesium-137, Plutonium-239, and Americium-241 from water at K-Basin and Strontium-90 from groundwater at Site 100N Area (N-Spring). A report detailing the results is available from DOE (DOE/RL-95-110).

DEMONSTRATION RESULTS:

During the SITE demonstration, the CPFM® treated about 10,000 gallons of water that contained about 100 micrograms per liter of uranium and 100 picoCuries per liter of gross alpha contamination. The demonstration consisted of three tests. The first test consisted of three 4-hour runs, at a flow rate of about 5 gallons per minute (gpm). For the second test, also run for 4 hours at 5 gpm, the influent water was pretreated with sodium sulfide. The third test

was a 15-hour run designed to determine the amount of contamination each filter pack could treat.

The CPFM® system removed up to 95 percent uranium and 94 percent gross alpha contamination. However, due to the significant variation in removal efficiencies between runs, average removal efficiencies were significantly less: 80 percent for uranium and 72 percent for gross alpha. Though removal is largely attributable to the colloid filter pack, uranium was significantly removed in runs one and four before colloid filter treatment. Significant gross alpha was also removed before colloid filter treatment in runs one and three. At less than the maximum removal efficiency, effluent from the CPFM® system did not meet the Colorado Water Quality Control Commission standards for discharge of waters from RFP.

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FUNDERBURK & ASSOCIATES (formerly HAZCON, INC.) (Dechlorination and Immobilization)

TECHNOLOGY DESCRIPTION:

This technology mixes hazardous wastes with cement (or fly ash), water, and one of 18 patented reagents, commonly known as Chloranan, to immobilize heavy metals. The developers also claim that certain chlorinated organics are dechlorinated by the treatment reagents.

Soils, sludges, and sediments can be treated in situ or excavated and treated ex situ. Sediments can be treated under water. In the finished product, immobilized metals have a very low solubility.

Ex situ treatment occurs in batches, with volumetric throughput rated at 120 tons per hour. The treatment process begins by adding Chloranan and water to the blending unit (see figure below). Waste is then added and mixed for 2 minutes. Cement or fly ash is added and mixed for a similar time. After 12 hours, the treated material hardens into a concrete-like mass that exhibits unconfined compressive strengths (UCS) ranging from 1,000 to

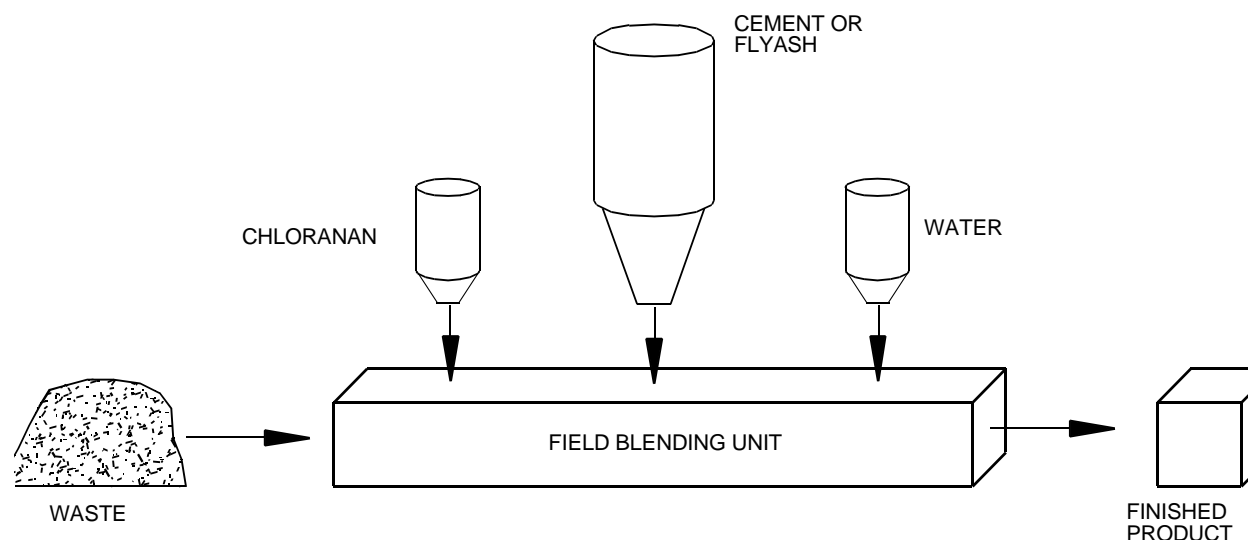
3,000 pounds per square inch (psi), with permeabilities of 10^{-9} centimeters per second (cm/sec). The hardened concrete-like mass can withstand several hundred freeze and thaw cycles.

WASTE APPLICABILITY:

The technology is applicable to solid wastes containing heavy metals and organics. The developer claims that, since the 1987 SITE demonstration, the technology has been refined to dechlorinate certain chlorinated organics and to immobilize other wastes, including those with high levels of metals. Wastes with organic and inorganic contaminants can be treated together. The process can treat contaminated material with high concentrations (up to 25 percent) of oil.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1987. The process was demonstrated in October 1987 at a former oil



Dechlorination and Immobilization Treatment Process

processing plant in Douglassville, Pennsylvania. The site soil contained high levels of oil and grease (250,000 parts per million [ppm]) and heavy metals (22,000 ppm lead), and low levels of volatile organic compounds (VOC) (100 ppm) and polychlorinated biphenyls (PCB) (75 ppm). The Applications Analysis Report (EPA/540/A5-89/001) and Technology Evaluation Report (EPA/540/5-89/001a) are available from EPA. A report on long-term monitoring may be also obtained from EPA. The technology has also been used to remediate a California Superfund site with zinc contamination as high as 220,000 ppm.

Since the demonstration in 1987, 17 additional reagent formulations have been developed. These reagents supposedly dechlorinate many chlorinated organics, including PCBs, ethylene dichloride, trichloroethene, and pentachlorophenol.

DEMONSTRATION RESULTS:

For the SITE demonstration, samples were taken after treatment at intervals of 7 days, 28 days, 9 months, and 22 months. Analytical results from these samples were generally favorable. The physical test results indicated a UCS between 220 and 1,570 psi. Low permeabilities (10^{-9} cm/sec) were recorded, and the porosity of the treated wastes was moderate. Durability test results showed no change in physical strength after the wet and dry and freeze and thaw cycles. The waste volume increased by about 120 percent. However, technology refinements now restrict volumetric increases to 15 to 25 percent. Using a smaller volume of additives reduces physical strength, but toxicity reduction is not affected.

The results of the leaching tests were mixed. Toxicity characteristic leaching procedure (TCLP) results for the stabilized wastes showed that concentrations of metals, VOCs, and semivolatile organic compounds (SVOC) were below 1 ppm. Lead concentrations in leachate decreased by a factor of 200 to below 100 parts per billion. VOC and SVOC concentrations in the TCLP leachate were not affected by treatment. Oil and grease concentrations were greater in the treated waste TCLP leachate (4 ppm) than in the untreated waste TCLP leachate (less than 2 ppm).

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GENERAL ATOMICS (Circulating Bed Combustor)

TECHNOLOGY DESCRIPTION:

General Atomics' circulating bed combustor (CBC) uses high velocity air to entrain circulating solids and create a highly turbulent combustion zone that destroys toxic hydrocarbons. The commercial-scale, 3-foot combustion chamber can treat up to 150 tons of contaminated soil daily, depending on the heating value of the feed material.

The CBC operates at lower temperatures than conventional incinerators (1,450 to 1,600 °F). The CBC's high turbulence produces a uniform temperature around the combustion chamber and hot cyclone. The CBC also completely mixes the waste material during combustion. Effective mixing and low combustion temperature reduce operating costs and potential emissions of such gases as nitrogen oxide (NO_x) and carbon monoxide (CO). Natural gas, fuel oil, or diesel can be used as auxiliary fuel. No auxiliary fuel is needed for waste streams with a net heating value greater than 2,900 British thermal units per pound.

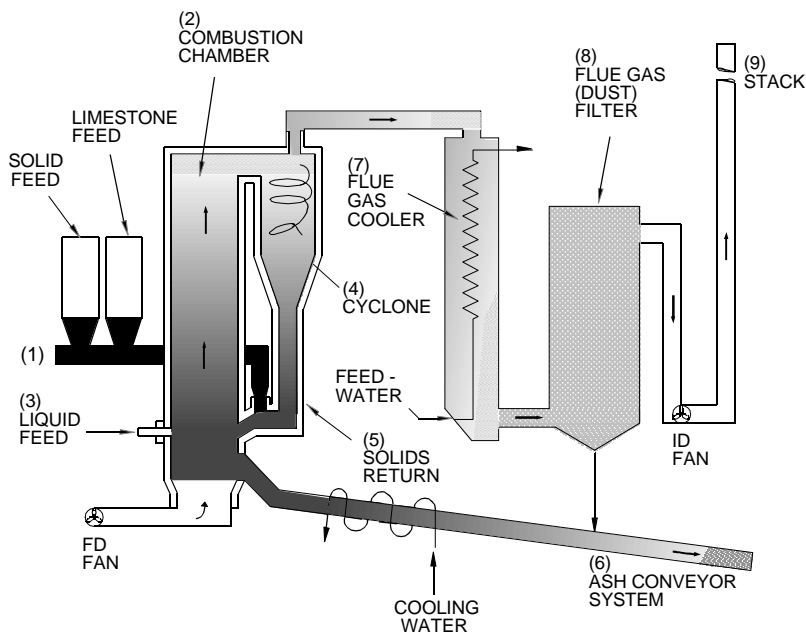
As shown in the figure below, waste material and

limestone are fed into the combustion chamber along with the recirculating bed material. The limestone neutralizes acid gases. A conveyor transports the treated ash out of the system for proper disposal. Hot combustion gases pass through a convective gas cooler and baghouse before they are released to the atmosphere.

WASTE APPLICABILITY:

The CBC process can treat liquids, slurries, solids, and sludges contaminated with corrosives, cyanides, dioxins and furans, inorganics, metals, organics, oxidizers, pesticides, polychlorinated biphenyls (PCB), phenols, and volatile organic compounds. The CBC is permitted under the Toxic Substances Control Act to burn PCBs in all 10 EPA regions, having demonstrated a 99.99 percent destruction removal efficiency (DRE).

Applications of the CBC include a variety of industrial wastes and contaminated site materials. Waste feed for the CBC must be sized to less than 1 inch. Metals in the waste do not inhibit



Circulating Bed Combustor (CBC)

performance and become less leachable after incineration. Treated residual ash can be replaced on site or stabilized for landfill disposal if metals exceed regulatory limits.

STATUS:

The CBC (formerly owned by Ogden Environmental Services) was accepted into the SITE Demonstration Program in 1986. A treatability study on wastes from the McColl Superfund site in California was conducted under the guidance of the SITE Program, EPA Region 9, and the California Department of Health Services in March 1989. A pilot-scale demonstration was conducted at the General Atomics research facility in San Diego, California using a 16-inch-diameter CBC. The demonstration was conducted on soil from the McColl Superfund Site in Fullerton, California.

Several 3-foot-diameter CBCs have been built and successfully operated. At the Swanson River project in Alaska, over 100,000 tons of PCB-contaminated soil was successfully treated to limits of detection that were far below allowable limits. The process took just over 3 years, from mobilization of the transportable unit to demobilization. The unit operated at over 85 percent availability all year, including winter, when temperatures were below -50 °F. The soil was delisted and returned to the original site. The unit has subsequently been moved to a Canadian site.

Another unit of similar size treated soils contaminated with #6 fuel oil. Over 14,000 tons of soil was successfully treated and delisted. Upon completion, the site was upgraded to permit operation as a merchant facility treating a wide range of materials from leaking underground fuel tanks at other sites. Two other units of the same size have been constructed in Germany for treatment of munitions wastes consisting of slurried explosives and propellant. These units have been operational since early 1995 and have been permitted under stringent German regulations.

DEMONSTRATION RESULTS:

During the SITE demonstration, the CBC performed as follows:

- Achieved DRE values of 99.99 percent or greater for principal organic hazardous constituents
- Minimized formation of products of incomplete combustion
- Met research facility permit conditions and California South Coast Basin emission standards
- Controlled sulfur oxide emissions by adding limestone and residual materials (fly ash and bed ash); these emissions were nonhazardous. No significant levels of hazardous organic compounds were found in the system, the stack gas, or the bed and fly ash.
- Minimized emissions of sulfur oxide, NO_x, and particulates. Other regulated pollutants were controlled to well below permit levels.

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GENERAL ENVIRONMENTAL CORPORATION (formerly HYDROLOGICS, INC.) (CURE®-Electrocoagulation Wastewater Treatment System)

TECHNOLOGY DESCRIPTION:

The CURE®-Electrocoagulation (CURE®) system is designed to remove ionic metal species and other charged particles from water (see figure below). Because many toxic metal ions such as nickel, lead, and chromates are held in solution by electrical charges, they will precipitate out of solution if they are neutralized with oppositely charged ions. The CURE® system is effective at breaking oily emulsions and removing suspended solids. The system improves on previous electrocoagulation methods through a unique geometrical configuration.

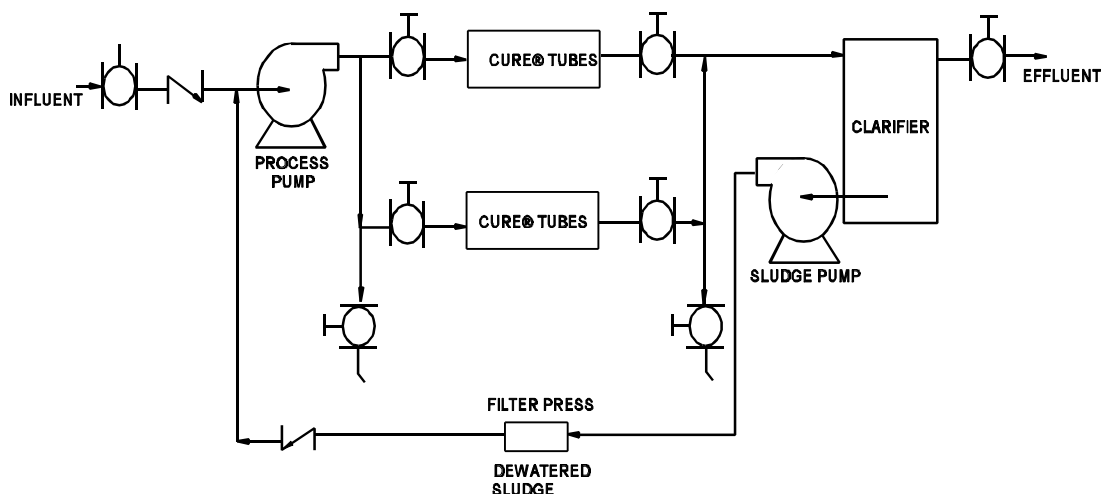
The CURE® system's patented geometry maximizes liquid surface contact between the anode and concentric cathode electrocoagulation tubes, thus minimizing the power requirements for efficient operation. The CURE® system allows the contaminated water to flow continuously through the cathode tube, enabling a direct current to pass uniformly through a water stream. The contaminated water then passes through the annular space between

the cathode and anode tubes and is exposed to sequential positive and negative electrical fields. Typical retention time is less than 20 seconds. Water characteristics such as pH, oxidation-reduction potential, and conductivity can be adjusted to achieve maximum removal efficiencies for specific contaminants.

After the treated water exits the electrocoagulation tubes, the destabilized colloids are allowed to flocculate and are then separated with an integrated clarifier system. Polymers can be added to enhance flocculation, but in most cases they are not required. The sludge produced by this process is usually very stable and acid-resistant. Tests have shown that sludges produced by the CURE® system pass the toxicity characteristic leaching procedure (TCLP) and are often disposed of as nonhazardous waste.

WASTE APPLICABILITY:

The CURE® system can treat a broad range of dissolved metals, including aluminum, arsenic, barium,



CURE®-Electrocoagulation System

cadmium, chromium, cyanide, iron, lead, nickel, uranium, and zinc. The system can also treat contaminants such as emulsified oils, suspended solids, paints, and dyes. Radionuclides were removed by the system at the Rocky Flats Environmental Technology Site (RFETS).

Because this system treats a wide range of contaminants, it is suited for industries and utilities such as plating, mining, electronics, industrial wastewater, as well as remediation projects.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1993. A bench-scale test of the technology was conducted in April 1995 to determine the ability of the system to remove radionuclides from solar evaporation water at RFETS. The system removed over 90 percent of uranium and plutonium from the test water. The technology was demonstrated during August and September 1995 at RFETS under a joint agreement between the Department of Energy, the State of Colorado, and EPA.

The technology has also been demonstrated at several private industrial facilities and is currently being used to remove metals and oily wastes from the following: plating wastewater at a jewelry manufacturing facility, industrial wastewaters from an engine manufacturing facility, cooling tower water at an industrial facility, and for several other industrial applications in the U.S. and internationally. Full- or pilot-scale units are available from General Environmental Corporation.

DEMONSTRATION RESULTS:

During the SITE demonstration, four 3-hour test runs were conducted at RFETS over a 2-week period. Prior to the demonstration, operating parameters were adjusted during several optimization runs.

The demonstration showed that the system removed 30 to 50 percent of uranium and 60 to 99 percent of plutonium from the solar pond water at RFETS. The radionuclide and metal content of the dewatered sludge indicated that these contaminants were highly concentrated in the sludge. Uranium and plutonium were only slightly leachable by TCLP and no metals

were leachable by TCLP. These results suggest that the sludge is very stable and resistant to breakdown.

The Demonstration Bulletin (EPA/540/MR-96/502), Technology Capsule (EPA/540/R-92/502a), and Innovative Technology Evaluation Report (EPA/540/R-96/502) are available from EPA.

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GEO-CON, INC. (In Situ Solidification and Stabilization Process)

TECHNOLOGY DESCRIPTION:

The in situ solidification and stabilization process immobilizes organic and inorganic compounds in wet or dry soils, using reagents (additives) to produce a cement-like mass. The basic components of this technology are (1) Geo-Con, Inc.'s (Geo-Con), deep soil mixing (DSM) system, to deliver and mix the chemicals with the soil in situ; and (2) a batch mixing plant to supply proprietary additives (see figure below).

The proprietary additives generate a complex, crystalline, connective network of inorganic polymers in a two-phase reaction. In the first phase, contaminants are complexed in a fast-acting reaction. In the second phase, macromolecules build over a long period of time in a slow-acting reaction.

The DSM system involves mechanical mixing and injection. The system consists of one set of cutting blades and two sets of mixing blades attached to a vertical drive auger, which rotates at approximately 15 revolutions per minute. Two conduits in the auger inject the additive slurry and supplemental water. Additives are injected on the downstroke; the slurry is further mixed upon auger withdrawal. The treated soil columns are 36 inches in diameter and

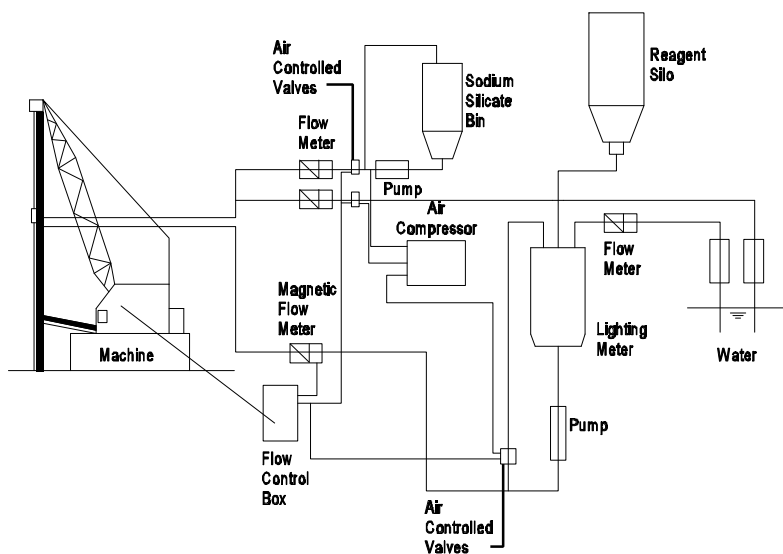
are positioned in an overlapping pattern of alternating primary and secondary soil columns.

WASTE APPLICABILITY:

The process treats soils, sediments, and sludge-pond bottoms contaminated with organic compounds and metals. The process has been laboratory-tested on soils containing polychlorinated biphenyls (PCB), pentachlorophenol, refinery wastes, and chlorinated and nitrated hydrocarbons.

STATUS:

A SITE demonstration was conducted as a joint effort between International Waste Technologies (IWT) and Geo-Con. The demonstration was conducted at the General Electric Service Shop site in Hialeah, Florida in April 1988. IWT provided the treatment reagent, specifically the proprietary additive (HWT-20), and Geo-Con provided both engineering and hardware for the in situ soil treatment. Two 10-by-20-foot areas were treated — one to a depth of 18 feet, and the other to a depth of 14 feet. Ten months after the demonstration, long-term monitoring tests were performed on the treated sectors. A four-auger process was later used to remediate the PCB-contaminated Hialeah site during



In Situ Solidification and Stabilization Process Flow Diagram

the winter and spring of 1990. Cooperative efforts between Geo-Con and IWT ended with the remediation of the Hialeah site.

Presently, Geo-Con offers the entire in situ stabilization package, including the treatment chemicals. Geo-Con has used the process to complete over 40 in situ stabilization projects throughout the United States. Significant projects completed to date include the following:

- Construction of a 110,000-square-foot, 60-foot-deep, soil-bentonite DSM wall to contain contaminated groundwater from a former waste pond. All DSM permeabilities were less than 10^{-7} centimeters per second (cm/s).
- Shallow soil mixing and stabilization of 82,000 cubic yards of contaminated soils at a former manufactured gas plant site. The site was declared clean and ultimately converted to a city park.

The DSM system augers have been scaled up to diameters as large as 12 feet. To date, Geo-Con has used this process to treat over 1 million cubic yards of contaminated soils and sludges.

DEMONSTRATION RESULTS:

The SITE demonstration yielded the following results:

- PCB immobilization appeared likely, but could not be confirmed because of low PCB concentrations in the untreated soil. Leachate tests on treated and untreated soil samples showed mostly undetectable PCB levels. Leachate tests performed 1 year later on treated soil samples showed no increase in PCB concentrations, indicating immobilization.
- Data were insufficient to evaluate the system's performance on other organic compounds and metals.

- Each test sample showed high unconfined compressive strength (UCS), low permeability, and low porosity. These physical properties improved in samples retested 1 year later, indicating the potential for long-term durability.
- Bulk density of the soil increased 21 percent after treatment. This treatment increased the treated soil volume by 8.5 percent and caused a small ground rise of 1 inch per foot of treated soil.
- The UCS of treated soil was satisfactory, with values up to 1,500 pounds per square inch.
- The permeability of the treated soil was satisfactory, decreasing to 10^{-6} and 10^{-7} cm/s compared to 10^{-5} cm/s for untreated soil.
- Data were insufficient to confirm immobilization of volatile and semivolatile organics. This may be due to organophilic clays present in the reagent.
- Process costs were \$194 per ton for the 1-auger machine used in the demonstration, and \$111 per ton for a commercial four-auger operation. More recent experience with larger scale equipment reduced process costs to about \$15 per ton plus the cost of reagents.

The Technology Evaluation Report (EPA/540/5-89/004a) and the Applications Analysis Report (EPA/540/A5-89/004) are available from EPA.

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GEOSAFE CORPORATION (In Situ Vitrification)

TECHNOLOGY DESCRIPTION:

Geosafe Corporation's (Geosafe) in situ vitrification (ISV) process uses electricity to melt soil or other earthen materials at temperatures of 1600 to 2000 °C, destroying organic pollutants by pyrolysis. Inorganic pollutants are immobilized within the vitrified glass and crystalline mass. Water vapor and organic pyrolysis products are captured in a hood, which draws the off-gases into a treatment system that removes particulates and other pollutants.

To begin the vitrification process, an array of four large electrodes is inserted into contaminated zones containing enough soil for melting to occur (see photograph below). A graphite starter is used to melt the adjacent soil, which then becomes the primary current-carrying medium for further processing. As power is applied, the melting continues downward and outward at an average rate of 4 to 6 tons per hour, or 1 to 2 inches per hour. The electrode array is lowered progressively, as the melt grows to the desired treatment depth. After cooling, a vitrified monolith with a glass and

microcrystalline structure remains. This monolith possesses high strength and excellent weathering and leaching properties.

Air flow through the hood is controlled to maintain a negative pressure. Excess oxygen is supplied for combustion of any organic pyrolysis by-products. Off-gases are treated by quenching, pH-controlled scrubbing, dewatering (mist elimination), heating (for dew point control), particulate filtration, and either activated carbon adsorption or thermal oxidation may be employed as a final off-gas polishing step.

Individual melt settings may encompass a total melt mass of up to 1,400 tons, a maximum width of 40 feet, and depths as great as 22 feet. Special settings to reach deeper contamination are also possible. Void volume and volatile material removal results in a 30 to 50 percent volume reduction for typical soils.

The mobile ISV system is mounted on three semi-trailers. Electric power may be provided by local utility or on-site diesel generator. Typical power



In Situ Vitrification Process Equipment

consumption ranges from 800 to 1,000 kilowatt-hours per ton of processed soil. The electrical supply system has an isolated ground circuit to provide safety.

WASTE APPLICABILITY:

The ISV process can destroy or remove organics and immobilize most inorganics in contaminated soils, sediments, sludges, or other earthen materials. The process has been tested on a broad range of volatile and semivolatile organic compounds, other organics including dioxins and polychlorinated biphenyls (PCB), and on most priority pollutant metals and heavy metal radio-nuclides. The process also treats large amounts of debris and waste materials present in soil.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1988. The demonstration of the process occurred during March and April 1994 at the former Parsons Chemical (Parsons) site in Grand Ledge, Michigan. The soil at Parsons was contaminated with pesticides, metals, and low levels of dioxins. The Innovative Technology Evaluation Report (EPA/540/R-94/520) and the Demonstration Bulletin (EPA/540/MR-94/520) are available from EPA.

In November 1995, Geosafe was issued a National Toxic Substances Control Act permit for the treatment of soils contaminated with up to 17,860 parts per million PCBs. All air emissions and vitrified product samples had nondetectable levels of PCBs and dioxins and furans. In December 1995, Geosafe completed the remediation of the Wasatch Chemical Superfund Site in Salt Lake City, Utah. This site contained about 6,000 tons of dioxin, pentachlorophenol, herbicide, pesticide, and other organic-contaminated soil and debris.

ISV has also been selected for the remediation of radioactively contaminated soil at Oak Ridge National Laboratory, Tennessee and an isolated nuclear test site in southern Australia. ISV is also being researched for the treatment of coal ash in Japan.

DEMONSTRATION RESULTS:

During the SITE demonstration, about 330 cubic yards (250 cubic meters) of a saturated clayey soil was vitrified in 10 days. This is the equivalent to a production rate of 53 tons per day.

The technology met cleanup levels specified by EPA Region 5 for chlordane, 4,4-dichlorodiphenyltrichloroethane, dieldrin, and mercury. Pesticide concentrations were nondetectable in the vitrified soil. Results also indicated that leachable mercury was below the regulatory guidelines (40 CFR part 261.64), and no target pesticides were detected in the leachate.

No target pesticides were detected in the stack gas samples, and metal emissions were below regulatory requirements. Continuous emission monitoring showed that total hydrocarbon and carbon monoxide emissions were within EPA Region 5 limits.

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GIS\SOLUTIONS, INC.
(GIS\Key™ Environmental Data Management System)

TECHNOLOGY DESCRIPTION:

GIS\Key™ is a comprehensive environmental database management system that integrates site data and graphics, enabling the user to create geologic cross-sections, boring logs, potentiometric maps, isopleth maps, structure maps, summary tables, hydrographs, chemical time series graphs, and numerous other maps and line graphs (see table below). The software is menu-driven, making it relatively simple to use. All system outputs meet Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) reporting requirements and are consistent with current industry practices.

GIS\Key™ can be a cost-effective tool to help manage hazardous waste site environmental data more effectively and accurately. GIS\Key™ allows project managers to focus on problem solving, because less time is required to enter, evaluate, and report the supporting site data. It also provides project managers access to environmental databases traditionally available only to computer specialists.

WASTE APPLICABILITY:

The GIS\Key™ software can be used at any Superfund site to facilitate the collection, reporting, and analysis of site data. The software is designed with numerous checks to assure the quality of the data, including comprehensive quality assurance/quality control protocols. System outputs, listed in the table below, are presentation-quality and meet RCRA and CERCLA reporting requirements. GIS\Key™ software includes an electronic laboratory import program that can immediately show where samples fall outside of historical data ranges, along with federal, state, and local action levels.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1992. The demonstration was held in August 1993 in San Francisco, California, and December 1993 in Washington, DC. The Demonstration Bulletin (EPA/540/MR-94/505), Technology Capsule (EPA/540/SR-94/505), Innovative Technology Evaluation Report (EPA/540/R-94/505), and project videotape are available from EPA.

CHEMISTRY	GEOLOGY	HYDROLOGY
<ul style="list-style-type: none"> • Isopleth maps of soil or water quality plan or section view • Graphs <ul style="list-style-type: none"> - Time series graphs - Chemical versus chemical and inter-well and intra-well - Concentration versus distance - Summary of statistics • Trilinear Piper diagrams • User alerts <ul style="list-style-type: none"> - When QA/QC results fall outside data quality objectives - When sample results fall outside historical ranges - When sample results exceed applicable regulatory standards • Presentation-quality data tables 	<ul style="list-style-type: none"> • Completely customizable boring logs • Geologic cross-section maps • Isopach maps • Structure maps • Modflow integration 	<ul style="list-style-type: none"> • Density-corrected water level, floating product, hydraulic conductivity, and contour maps • Water elevation and floating product thickness versus time graphs • Flow versus time and chemical flux graphs • Modflow integration

GIS\Key™ Environmental Data Management System Outputs

The GIS\Key™ software is in use at two Superfund sites: the Crazyhorse site near Salinas, California, and the Moffett Field site near San Jose, California.

The U.S. Air Force's Environmental Data Management and Decision Support working group is testing the effectiveness of the GIS\Key™ technology at Norton Air Force Base in California. The technology is also being used by consultants at over 20 other U.S. Air Force bases.

The GIS\Key™ software can directly export data into the leading three-dimensional visualization systems. These systems produce three-dimensional contaminant plume models and groundwater flow models as well as fence diagrams. GIS\Solutions, Inc., can provide an optional software module for three-dimensional modeling that runs on the Microsoft® Windows™ operating system.

Improper use of certain AutoCAD® commands can cause problems with basemap integrity. GIS\Key™ includes limited audit or transaction logging capabilities. GIS\Key™ data consistency and validity checks could be improved as it is possible to enter invalid data. Site data related to ecological assessment and air emissions is not managed by this software.

DEMONSTRATION RESULTS:

The goal of the SITE demonstration was to evaluate whether the software performs the functions claimed by the developer and assess the accuracy of the GIS\Key™ output. Also, GIS\Key™ procedures were reviewed to ensure data integrity, to evaluate the general usability of GIS\Key™, and to compare GIS\Key™ features to user requirements.

Results from the SITE demonstration indicated that the GIS\Key™ software generated the four types of contour maps necessary to assist in groundwater mapping: hydrogeologic maps, chemical concentration isopleths, geologic structure maps, and geologic structure thickness isopach maps. Several advanced chemistry reports and construction and borehole summary tables were also automatically prepared using customized GIS\Key™ menu commands. The system

automated well and borehole logs based on the information contained in the database.

GIS\Key™ provided several editable reference lists, including a list of regulatory thresholds, test methods, and a list of chemical names, aliases, and registry numbers.

The GIS\Key™ database menu provided commands for electronic database import and export. Any of the database files used by GIS\Key™ can be used with the general import and export commands available in the database menu.

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GRACE BIOREMEDIATION TECHNOLOGIES (DARAMEND™ Bioremediation Technology)

TECHNOLOGY DESCRIPTION:

The GRACE Bioremediation Technologies organic amendment-enhanced bioremediation technology (DARAMEND™) is designed to degrade many organic contaminants in industrial soils and sediments, including pentachlorophenol (PCP), polynuclear aromatic hydrocarbons (PAH), and petroleum hydrocarbons. The technology has been applied both in situ and ex situ. In either case, soil may be treated in lifts up to 2 feet deep using available mixing equipment. The technology may also be applied ex situ, as a biopile.

The technology treats batches of soil using DARAMEND™ soil amendments. These amendments are introduced using conventional agricultural equipment (see photograph below), followed by regular tilling and irrigation. DARAMEND™ soil amendments are solid-phase products prepared from natural organic materials to have soil-specific particle size distribution, nutrient content, and nutrient release kinetics. Soil amendments sharply increase the ability of the soil matrix to supply water and nutrients to the

microorganisms that degrade the hazardous compounds. The amendments can also transiently bind contaminants, reducing the acute toxicity of the soil aqueous phase. This reduction allows microorganisms to survive in soils containing very high concentrations of toxic compounds.

DARAMEND™ treatment involves three fundamental steps. First, the treatment area is prepared. For the ex situ application, a lined treatment cell is constructed. In situ application requires the treatment area to be cleared and ripped to reduce soil compaction. Second, the soil is pretreated; this includes removing debris larger than 4 inches, such as metal or rocks, that may damage the tilling equipment. Sediments under-going treatment must be dewatered. And third, the DARAMEND™ soil amendment is incorporated, usually at 1 percent to 5 percent by weight, followed by regular tilling and irrigating.

Soil is tilled with a rotary tiller to reduce variation in soil properties and contaminant concentrations. Tilling also incorporates the required soil amendments and helps deliver oxygen to



DARAMEND™ Bioremediation Technology

contaminant-degrading microorganisms.

An irrigation system is used to maintain soil moisture in the desired range. If the treatment area is not covered, leachate or surface runoff caused by heavy precipitation is collected and reapplied to the soil as needed.

Equipment needed to implement this technology includes a rotary tiller, irrigation equipment, and excavation and screening equipment. Depending on site-specific factors such as contaminant type and initial concentration, and project schedule and climate, a waterproof cover may be constructed over the treatment area.

WASTE APPLICABILITY:

The DARAMEND™ technology can treat soil, sediment, and other solid wastes such as lagoon sludge. These matrices may be contaminated by a wide range of organic compounds including, but not limited to, PAHs, PCP, petroleum hydrocarbons, and phthalates. Matrices of lead, manganese, and zinc have been effectively treated with the DARAMEND™ technology.

STATUS:

This technology was accepted into the SITE Demonstration Program in spring 1993. The ex situ application of the technology was demonstrated from fall 1993 to summer 1994 at the Domtar Wood Preserving facility in Trenton, Ontario, Canada. The demonstration was one component of a 5,000-ton remediation project underway at the site.

Currently, the DARAMEND™ technology and cycled modification is being applied on a large scale, and is awaiting regulatory approval for application at four sites in the U.S. In addition, the technology is being applied at a number of Canadian sites, including a 2,500-ton biopile in Eastern Canada, and two projects targeting pesticides and herbicides in Ontario.

DEMONSTRATION RESULTS:

In the ex situ demonstration area, the DARAMEND™ technology achieved the following overall reductions: PAHs, 94 percent (1,710 milligram/kilogram [mg/kg] to 98 mg/kg); chlorophenols, 96 percent (352 mg/kg to 13.6 mg/kg); and TPH, 87 percent. These reductions were achieved in 254 days of treatment, including winter days when no activity occurred because of low soil temperatures. The control area showed a reduction of 41 percent in PAH concentrations; no reduction was seen in the concentration of either chlorinated phenols or TPH during the treatment time. Results from the toxicity analysis (earthworm mortality and seed germination) showed that the toxicity was eliminated or greatly reduced in the treated soil.

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GRUPPO ITALIMPRESSE
(developed by SHIRCO INFRARED SYSTEMS, INC.)
(Infrared Thermal Destruction)

TECHNOLOGY DESCRIPTION:

The infrared thermal destruction technology is a mobile thermal processing system that uses electrically powered silicon carbide rods to heat organic wastes to combustion temperatures. Any remaining combustibles are incinerated in an afterburner. One configuration for this mobile system (see figure below) consists of four components: (1) an electric-powered infrared primary chamber; (2) a gas-fired secondary combustion chamber; (3) an emissions control system; and (4) a control center.

Waste is fed into the primary chamber and exposed to infrared radiant heat (up to 1,850 °F) provided by silicon carbide rods above the conveyor belt. A blower delivers air to selected locations along the belt to control the oxidation rate of the waste feed.

The ash material in the primary chamber is quenched with scrubber water effluent. The ash is then conveyed to an ash hopper, where it is removed to a holding area and analyzed for organic contaminants such as polychlorinated biphenyls (PCB).

Volatile gases from the primary chamber flow into the secondary chamber, which uses higher temperatures, greater residence time, turbulence, and

supplemental energy (if required) to destroy these gases. Gases from the secondary chamber are ducted through the emissions control system. In the emissions control system, the particulates are removed in a venturi scrubber. Acid vapor is neutralized in a packed tower scrubber. An induced draft blower draws the cleaned gases from the scrubber into the free-standing exhaust stack. The scrubber liquid effluent flows into a clarifier, where scrubber sludge settles and is removed for disposal. The liquid then flows through an activated carbon filter for reuse or to a publicly owned treatment works for disposal.

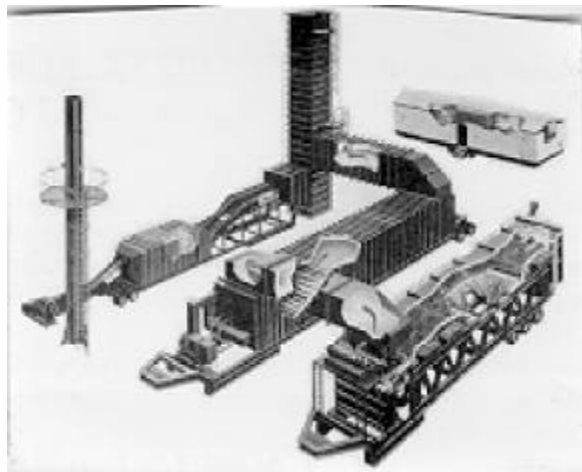
WASTE APPLICABILITY:

This technology is suitable for soils or sediments with organic contaminants. Liquid organic wastes can be treated after mixing with sand or soil. Optimal waste characteristics are as follows:

- Particle size, 5 microns to 2 inches
- Moisture content, up to 50 percent by weight
- Density, 30 to 130 pounds per cubic foot
- Heating value, up to 10,000 British thermal units per pound
- Chlorine content, up to 5 percent by weight
- Sulfur content, up to 5 percent by weight
- Phosphorus, 0 to 300 parts per million (ppm)
- pH, 5 to 9
- Alkali metals, up to 1 percent by weight

STATUS:

EPA conducted two evaluations of the infrared thermal destruction technology. A full-scale unit was evaluated during August 1987 at the Peak Oil Superfund site in Brandon, Florida. The system treated nearly 7,000 cubic yards of waste oil sludge containing PCBs and lead. A pilot-scale demonstration took place at the Rose Township-Demod Road Superfund site in Michigan during November 1987. Organics, PCBs, and metals in soil were the target waste compounds. Two



Mobile Thermal Processing System

Applications Analysis Reports (EPA/540/A5-89/010 and EPA/540/A5-89/007) and two Technology Evaluation Reports (EPA/540/5-88/002a and EPA/540/5-89/007a) are available from EPA. In addition, the technology has been used to remediate PCB contamination at the Florida Steel Corporation and the LaSalle Electric Superfund sites.

This technology is no longer available through vendors in the United States. For further information about the technology, contact the EPA Project Manager.

DEMONSTRATION RESULTS:

The results from the two SITE demonstrations are summarized below.

- PCBs were reduced to less than 1 ppm in the ash, with a destruction removal efficiency (DRE) for air emissions greater than 99.99 percent (based on detection limits).
- In the pilot-scale demonstration, the Resource Conservation and Recovery Act standard for particulate emissions (0.08 gram per dry standard cubic foot) was achieved. In the full-scale demonstration, however, this standard was not met in all runs because of scrubber inefficiencies.
- Lead was not immobilized; however, it remained in the ash. Significant amounts were not transferred to the scrubber water or emitted to the atmosphere.

- The pilot-scale unit demonstrated satisfactory performance with high feed rate and reduced power consumption when fuel oil was added to the waste feed and the primary chamber temperature was reduced.
- Economic analysis suggests an overall waste remediation cost of less than \$800 per ton.

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HIGH VOLTAGE ENVIRONMENTAL APPLICATIONS, INC.
(formerly ELECTRON BEAM RESEARCH FACILITY, FLORIDA
INTERNATIONAL UNIVERSITY, and UNIVERSITY OF MIAMI)
(High-Energy Electron Irradiation)

TECHNOLOGY DESCRIPTION:

High-voltage electron irradiation of water produces a large number of very reactive chemical species, including the aqueous electron (e_{aq}^-), the hydrogen radical ($H\cdot$), and the hydroxyl radical ($OH\cdot$). These short-lived intermediates break down organic contaminants in aqueous wastes.

In the principal reaction, the aqueous electron transfers to halogen-containing compounds, breaking the halogen-carbon bond and liberating halogen anions such as chloride (Cl^-) or bromide (Br^-). The hydroxyl radical can undergo addition or hydrogen abstraction reactions, producing organic free radicals that decompose in the presence of other hydroxyl radicals and water. In most cases, organics are converted to carbon dioxide, water, and salts. Lower molecular weight aldehydes, haloacetic acids, and carboxylic acids form at low concentrations in some cases.

During the high-voltage electron irradiation process,

electricity generates high energy electrons. The electrons are accelerated by the voltage to approximately 95 percent of the speed of light. They are then directed into a thin stream of water or sludge. All reactions are complete in less than 0.1 second. The electron beam and waste flow are adjusted to deliver the necessary dose of electrons. Although this is a form of ionizing radiation, there is no residual radioactivity.

High Voltage Environmental Applications, Inc. (High Voltage), has developed a mobile facility to demonstrate the treatment process (see photograph below).

WASTE APPLICABILITY:

This treatment process can effectively treat more than 100 common organic compounds. These compounds include the following:

- Trihalomethanes (such as chloroform), which



The Mobile Electron Beam Hazardous Waste Treatment System

are found in chlorinated drinking water

- Chlorinated solvents, including carbon tetrachloride, trichloroethane, tetrachloroethene (PCE), trichloroethene (TCE), ethylene dibromide, dibromochloropropane, hexachlorobutadiene, and hexachloroethane
- Aromatics found in gasoline, including benzene, toluene, ethylbenzene, and xylene (BTEX)
- Chlorobenzene and dichlorobenzenes
- Phenol
- Dieldrin, a persistent pesticide
- Polychlorinated biphenyls
- A variety of other organic compounds

The treatment process is appropriate for removing various hazardous organic compounds from aqueous waste streams and sludges.

STATUS:

The high-energy electron irradiation process was accepted into the SITE Emerging Technology Program (ETP) in June 1990. For further information on the pilot-scale facility evaluated under the ETP, refer to the Emerging Technology Bulletins (EPA/540/F-93/502, EPA/540/F-92/009, and EPA/540/F-93/509), which are available from EPA. Based on results from ETP, the process was invited to participate in the Demonstration Program.

The ability of the technology to treat contaminated soils, sediments, or sludges is also being evaluated under the ETP. For further information on this evaluation, refer to the High Voltage profile in the ETP section (ongoing projects).

The treatment process was demonstrated at the U.S. Department of Energy's Savannah River site in Aiken, South Carolina during two different periods totaling 3 weeks in September and November 1994. The demonstration of a trailer-mounted treatment system took place on a portion of the Savannah River site known as M-Area.

DEMONSTRATION RESULTS:

During the demonstration, the system treated about 70,000 gallons of M-Area groundwater contaminated with volatile organic compounds (VOC). The principal groundwater contaminants were TCE and PCE, which were present at concentrations of about 27,000 and 11,000 micrograms per liter ($\mu\text{g/L}$), respectively. The groundwater also contained low levels of cis-1,2-dichloroethene ($40 \mu\text{g/L}$). The following compounds were also spiked into the influent stream at approximately $500 \mu\text{g/L}$: 1,2-dichloroethane, carbon tetrachloride, 1,1,1-trichloroethane, chloroform, and BTEX.

The highest VOC removal efficiencies were observed for TCE (99.5 percent), PCE (99.0 percent), and dichloroethene (greater than 99 percent). Removal efficiencies for chlorinated spiking compounds ranged from 68 to 98 percent, and removal efficiencies for BTEX ranged from 88 to 99.5 percent.

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HORSEHEAD RESOURCE DEVELOPMENT CO., INC. **(Flame Reactor)**

TECHNOLOGY DESCRIPTION:

The Horsehead Resource Development Co., Inc. (HRD), flame reactor system is a patented, hydrocarbon-fueled, flash-smelting system that treats residues and wastes contaminated with metals (see figure below). The reactor processes wastes with hot (greater than 2,000 °C) reducing gases produced by combusting solid or gaseous hydrocarbon fuels in oxygen-enriched air.

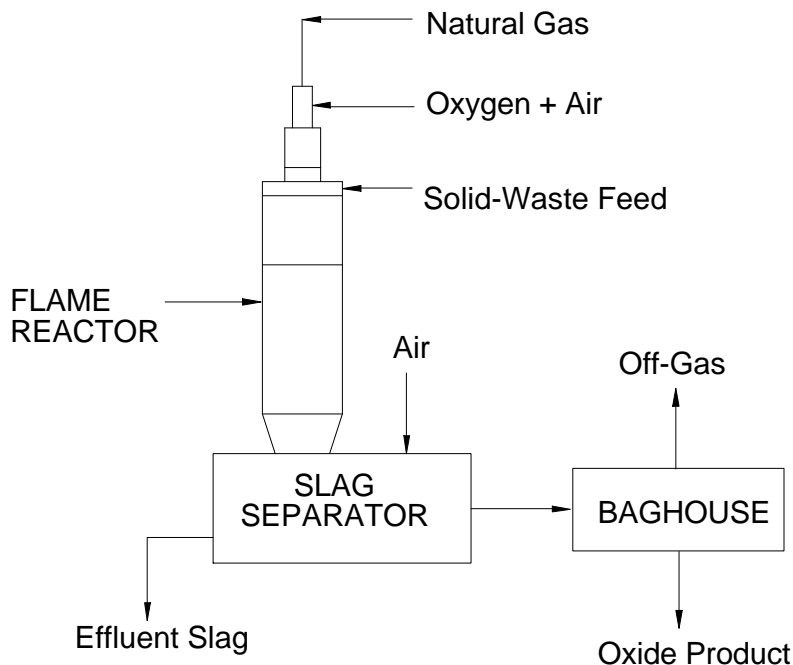
In a compact, low-capital cost, water-cooled reactor, the feed materials react rapidly, allowing a high waste throughput. The end products are glass-like slag; a potentially recyclable, heavy metal-enriched oxide; and in some cases, a metal alloy. The glass-like slag is not toxicity characteristic leaching procedure (TCLP) leachable. The volatile metals are fumed and captured in a baghouse; nonvolatile metals partition to the slag or may be separated as a molten alloy. Organic compounds should be destroyed at the elevated temperature of the flame reactor technology. Volume reduction (of waste to

slag plus oxide) depends on the chemical and physical properties of the waste.

In general, the system requires that wastes be dry enough (less than 5 percent total moisture) to be pneumatically fed and fine enough (less than 200 mesh) to react rapidly. HRD claims larger particles (up to 20 mesh) can be processed; however, the efficiency of metals recovery is decreased. The prototype system has a capacity of 1 to 3 tons per hour. According to HRD, individual units can be scaled to a capacity of 7 tons per hour.

WASTE APPLICABILITY:

The flame reactor system can be applied to granular solids, soil, flue dusts, slags, and sludges that contain heavy metals. HRD claims that the flame reactor technology has successfully treated the following wastes: (1) electric arc furnace dust, (2) lead blast furnace slag, (3) soil, (4) iron residues, (5) primary copper flue dust, (6) lead smelter nickel matte, (7) zinc plant leach residues and purification



HRD Flame Reactor Process Flow

residues, (8) brass mill dusts and fumes, and (9) electroplating sludges.

The system has treated wastes with the following metal species and concentrations: zinc (up to 40 percent); lead (up to 10 percent); chromium (up to 4 percent); cadmium (up to 3 percent); arsenic (up to 1 percent); copper (up to 8 percent); cobalt; and nickel. According to HRD, the system can also treat soils that are contaminated with a variety of toxic organics.

STATUS:

This technology was accepted into the SITE Demonstration Program in 1990. Currently, the prototype flame reactor system operates as a stationary unit at HRD's facility in Monaca, Pennsylvania. EPA and HRD believe that a mobile system could be designed and constructed for on-site treatment of hazardous waste.

The SITE demonstration was conducted in March 1991 using secondary lead smelter soda slag from the National Smelting and Refining Company (NSR) Superfund site in Atlanta, Georgia. The demonstration was conducted at the Monaca, Pennsylvania facility under a Resource Conservation and Recovery Act research, development, and demonstration permit. This permit allows treatment of wastes containing high concentrations of metals, but only negligible concentrations of organics.

The major objectives of the SITE technology demonstration were to investigate the reuse potential of the recovered metal oxides, evaluate the levels of contaminants in the residual slag and their leaching potential, and determine the efficiency and economics of processing.

A 30,000-standard-tons-per-year commercial flame reactor system processes steel mill baghouse dust (K061) at the North Star Steel Mini Mill near Beaumont, Texas. The plant was activated June 1, 1993 and is reported to be performing as designed.

DEMONSTRATION RESULTS:

Approximately 72 tons of NSR waste material were processed during the demonstration. Partial test results are shown in the table below.

Metal Concentration Ranges in Influent and Effluent

	Waste Feed (mg/kg)*	Effluent Slag (mg/kg)	Oxide Product (mg/kg)
Arsenic	428-1,040	92.1-1,340	1,010-1,170
Cadmium	356-512	<2.3-13.5	1,080-1,380
Copper	1,460-2,590	2,730-3,890	1,380-1,780
Iron	95,600-130,000	167,000-228,000	29,100-35,600
Lead	48,200-61,700	1,560-11,400	159,000-184,000
Zinc	3,210-6,810	709-1,680	10,000-16,200

* milligrams per kilogram

All effluent slag passed toxicity characteristic leaching procedure criteria. The oxide was recycled to recover lead. The Technology Evaluation Report (EPA/540/5-91/005) and the Applications Analysis Report (EPA/540/A5-91/005) are available from EPA.

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HRUBETZ ENVIRONMENTAL SERVICES, INC. (HRUBOUT® Process)

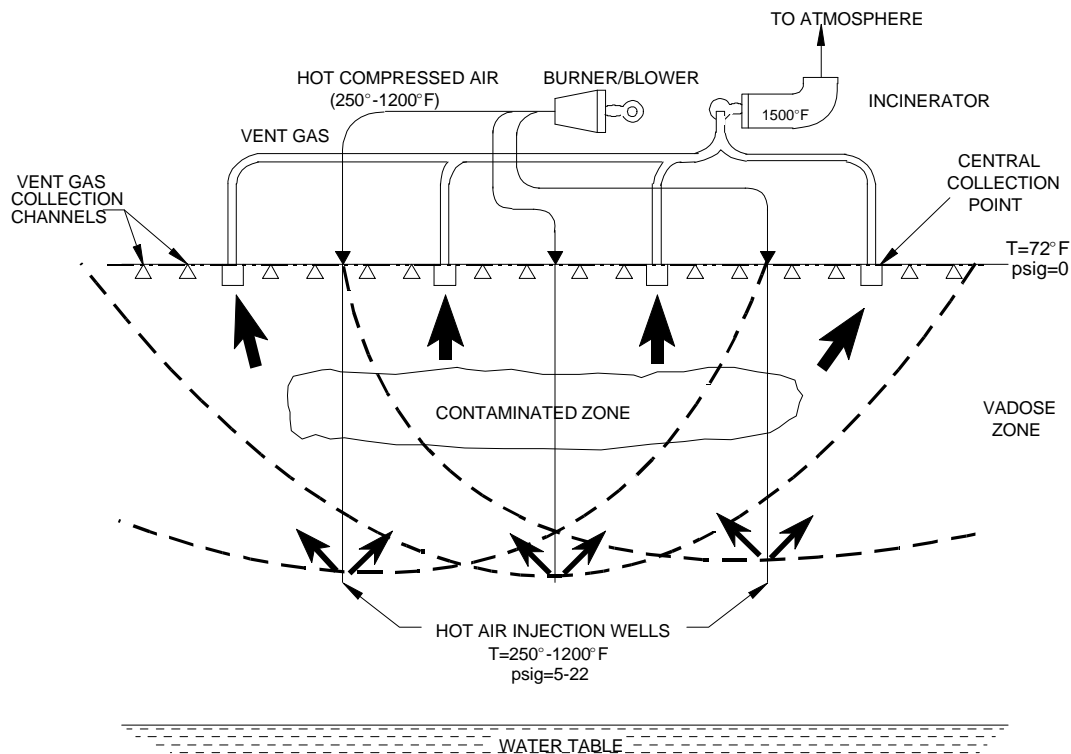
TECHNOLOGY DESCRIPTION:

The HRUBOUT® process is a thermal, in situ and ex situ treatment process designed to remove volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from contaminated soils. The in situ process is shown in the figure below. Heated air is injected into the soil below the contamination zone, evaporating soil moisture and removing volatile and semivolatile hydrocarbons. As the water evaporates, soil porosity and permeability increase, further facilitating the air flow at higher temperatures. As the soil temperature increases further, the less volatile constituents volatilize or are thermally oxidized.

Injection wells are drilled in a predetermined distribution pattern to depths below the contamination zone. The wells are equipped with steel casing, perforated at the bottom, and

cemented into the hole above the perforations. Heated, compressed air is introduced at temperatures of up to 1,200 °F, and the pressure is slowly increased. As the air progresses upward through the soil, the moisture is evaporated, removing the VOCs and SVOCs. A surface collection system captures the exhaust gases under negative pressure. These gases are transferred to a thermal oxidizer, where the hydrocarbons are thermally destroyed in an incinerator at a temperature of 1,500 °F.

The air is heated in an adiabatic burner at 2.9 million British thermal units per hour (MMBtu/hr). The incinerator has a rating of 3.1 MMBtu/hr. The air blower can deliver up to 8,500 pounds per hour. The units employ a fully modulating fuel train that is fueled by natural gas or propane. All equipment is mounted on custom-designed mobile units and can operate 24 hours per



HRUBOUT® Process

day.

WASTE APPLICABILITY:

The HRUBOUT® process can remediate soils contaminated with halogenated or nonhalogenated organic volatiles and semivolatiles, such as gasoline, diesel oil, jet fuel, heating oil, chemical solvents or other hydrocarbon compounds.

STATUS:

The HRUBOUT® process was accepted into the SITE Demonstration Program in July 1992. The technology was demonstrated at Kelly Air Force Base in San Antonio, Texas from January through February 1993. A 30-by-40-foot area of an 80,000-gallon JP-4 jet fuel spill site was chosen as the treatment area. Six heated air injection wells, spaced on a 3-by-2 grid 10 feet apart, were drilled to a depth of approximately 20 feet. The Demonstration Bulletin (EPA/540/MR-93/524) is available from EPA.

In September 1993, an in situ project was completed at the Canadian Forces military base in Ottawa, Ontario, Canada. Levels up to 1,900 parts per million (ppm) of total petroleum hydrocarbons (TPH) were encountered over a 17-by-17-foot area on the base. Five injection wells were drilled to a depth of 30 feet. After 12 days of treatment, borehole samples ranged from nondetect to 215 ppm TPH, meeting closure requirements of 450 ppm TPH.

The containerized version of the HRUBOUT® process was tested in July 1993 at a west Texas site contaminated with Varsol, or naphtha. The soil was excavated for treatment in Hrubetz's insulated container. Analysis of untreated soil revealed TPH at 1,550 ppm. Three loads were treated for about 60 to 65 hours each. Posttreatment samples ranged from nondetect to 7 ppm TPH, meeting the Texas Natural Resource Conservation Commission's background target level of 37 ppm. Large-scale mobile container units, holding up to 40 cubic yards and capable of ex situ treatment of a load in 8 hours, are under development.

The ex situ version of the technology was selected to remediate a site in Toronto, Ontario, Canada, which consisted of about 1,500 cubic yards (yd³) of soil contaminated with gasoline and diesel. Soil contamination was measured at 200 ppm TPH. Following treatment, seven soil samples were collected. Two samples had detectable concentrations of TPH (25 and 37 ppm) and the remaining five samples had nondetectable levels of TPH, achieving the 100 ppm TPH cleanup goal.

About 100 yd³ of toluene-contaminated soil was remediated in Orlando, Florida using the soil pile process with a smaller 5-ton unit. A composite analysis of the excavated soil found toluene at concentrations of up to 1,470 parts per billion; nondetect levels were required for closure. A composite soil sample collected after 96 hours of operation met the closure criteria.

Four patents have been granted, and additional patents are pending. The process was approved by the Texas Natural Resources Conservation Commission in 1991.

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HUGHES ENVIRONMENTAL SYSTEMS, INC. (Steam Enhanced Recovery Process)

TECHNOLOGY DESCRIPTION:

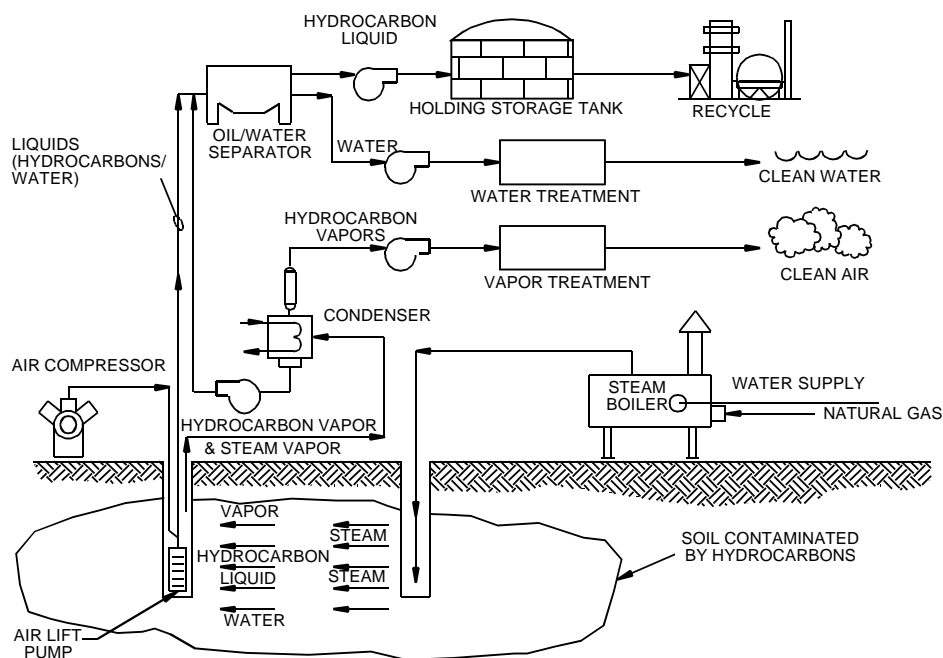
The Steam Enhanced Recovery Process (SERP) removes most volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) from perched groundwater and contaminated soils both above and below the water table (see figure below). The technology is applicable to the in situ remediation of contaminated soils below ground surface and below or around permanent structures. The process accelerates contaminant removal rates and can be effective in all soil types.

Steam is forced through the soil by injection wells to thermally enhance the recovery of VOCs and SVOCs. Extraction wells are used for two purposes: to pump and treat groundwater, and to transport steam and vaporized contaminants to the surface. Recovered nonaqueous liquids are separated by gravity separation. Hydrocarbons are collected for recycling, and water is treated before being discharged to a storm drain or sewer. Vapors

can be condensed and treated by any of several vapor treatment techniques (for example, thermal oxidation and catalytic oxidation). The technology uses readily available components such as extraction and monitoring wells, manifold piping, vapor and liquid separators, vacuum pumps, and gas emission control equipment.

WASTE APPLICABILITY:

The SERP can extract VOCs and SVOCs from contaminated soils and perched groundwater. Compounds suitable for treatment are petroleum hydrocarbons such as gasoline and diesel and jet fuel; solvents such as trichloroethene, trichloroethane, and dichlorobenzene; or a mixture of these compounds. After application of the process, subsurface conditions are excellent for biodegradation of residual contaminants. The process cannot be applied to contaminated soil very near the ground surface unless a cap exists.



Steam Enhanced Recovery Process

STATUS:

This technology was accepted into the SITE Demonstration Program in 1991. The demonstration of the technology began in August 1991 and was completed in September 1993. The demonstration took place in Huntington Beach, California at a site contaminated by a large diesel fuel spill. The Demonstration Bulletin (EPA/540/MR-94/510), Technology Capsule (EPA/540/R-94/510a), and Innovative Technology Evaluation Report (EPA/540/R-94/510) are available from EPA.

For more information regarding this technology, see the profiles for Berkeley Environmental Restoration Center (completed projects) or Praxis Environmental Technologies, Inc., in the Demonstration Program section (ongoing profiles).

This technology is no longer available through a vendor. For further information on the technology, contact the EPA Project Manager.

DEMONSTRATION RESULTS:

Evaluation of the posttreatment data suggests the following conclusions:

- The geostatistical weighted average for total petroleum hydrocarbon (TPH) concentrations in the treated soils was 2,290 milligrams per kilogram (mg/kg). The 90 percent confidence interval for this average concentration is 996 mg/kg to 3,570 mg/kg, indicating a high probability that the technology did not meet the cleanup criterion. Seven percent of soil samples had TPH concentrations in excess of 10,000 mg/kg.

- The geostatistical weighted average for total recoverable petroleum hydrocarbon (TRPH) concentrations was 1,680 mg/kg, with a 90 percent confidence interval of 676 mg/kg to 2,680 mg/kg. Levels of benzene, toluene, ethylbenzene, and xylenes (BTEX) were below the detection limit (6 micrograms per kilogram) in treated soil samples; BTEX was detected at low mg/kg levels in a few pretreatment soil samples.
- Analysis of triplicate treated soil samples showed marked variability in soil contaminant concentration over short distances. Analogous results for TPH and TRPH triplicate samples suggest that the contaminant concentration variability exists within the site soil matrix and is not the result of analytical techniques. This variability is the reason that confidence intervals for the average concentrations are so large.
- The data suggest that lateral or downward migration of contaminants did not occur during treatment.

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IIT RESEARCH INSTITUTE/ BROWN AND ROOT ENVIRONMENTAL (Radio Frequency Heating)

TECHNOLOGY DESCRIPTION:

Radio frequency heating (RFH) is an in situ process that uses electromagnetic energy to heat soil and enhance soil vapor extraction (SVE). Developed by IIT Research Institute, the patented RFH technique heats a discrete volume of soil using rows of vertical electrodes embedded in soil (or other media). Heated soil volumes are bounded by two rows of ground electrodes with energy applied to a third row midway between the ground rows. The three rows act as a buried triplate capacitor. When energy is applied to the electrode array, heating begins at the top center and proceeds vertically downward and laterally outward through the soil volume. The technique can heat soils to over 300 °C.

RFH enhances SVE in two ways: (1) contaminant vapor pressures are increased by heating, and (2) the soil permeability is increased by drying. Extracted

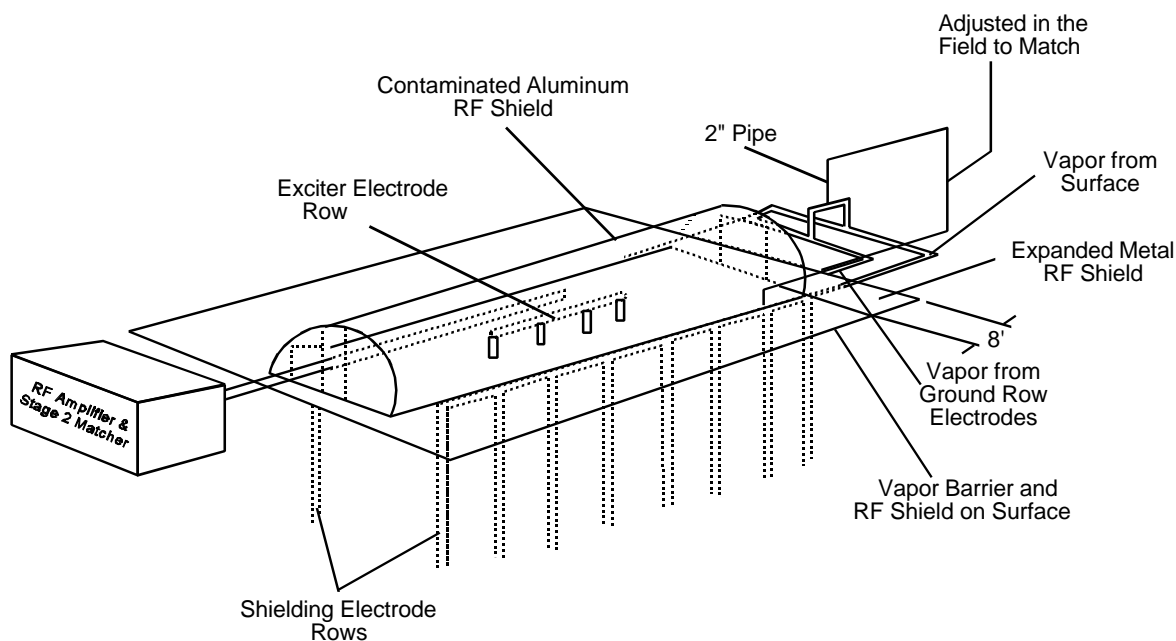
vapor can then be treated by a variety of existing technologies, such as granular activated carbon or incineration.

WASTE APPLICABILITY:

RFH can treat petroleum hydrocarbons, volatile organic compounds (VOC), semivolatile organic compounds (SVOC), and pesticides in soils. The technology is most efficient in subsurface areas with low groundwater recharge. In theory, the technology should be applicable to any polar compound in any nonmetallic media.

STATUS:

The RFH technique was accepted into the SITE Demonstration Program in summer 1992. The technique was demonstrated in August 1993 at Kelly Air Force Base (AFB), Texas, as part of a



In Situ Radio Frequency Heating System

joint project with the U.S. Air Force. Brown and Root Environmental was the prime contractor evaluating and implementing RFH for the U.S. Air Force. A field demonstration of the KAI Technologies, Inc. (KAI), RFH technology was completed in June 1994 at the same site for comparison. The Demonstration Bulletin (EPA/540/MR-94/527), Technology Capsule (EPA/540/R-94/527a), and the Innovative Technology Evaluation Report (EPA/540/R-94-527) are available from EPA. For further information on the KAI technology, see the profile in the Demonstration Program section (completed projects).

In 1995, the RFH technique was tested at the former chemical waste landfill at Sandia National Laboratories in Albuquerque, New Mexico. Approximately 800 cubic yards of silty soil was heated. Preliminary results indicate that the contaminant concentration in the extracted vapors increased by a factor of 10 compared to in situ venting.

Two previous field tests were completed using in situ RFH. The first test was completed at a fire training pit, located at the Volk Air National Guard Base in Camp Douglas, Wisconsin. The sandy soil in the pit was contaminated with jet fuel. The second test was completed at Rocky Mountain Arsenal in Colorado, where clayey soil was contaminated by organochlorine pesticides.

DEMONSTRATION RESULTS:

Under the SITE demonstration, statistical analyses for the design treatment zone indicate that total recoverable petroleum hydrocarbons, pyrene, and bis(2-ethylhexyl)phthalate exhibited statistically significant decreases (at the 95 and 97.5 percent confidence levels). Chlorobenzene concentrations appeared to increase during treatment, possibly due to volatilization of chlorobenzene present in the groundwater.

Significant concentrations of 2-hexanone, 4-methyl-2-pentanone, acetone, and methyl ethyl ketone were found in the treated soils, although virtually no ketones were found before treatment. Soil temperatures as high as 1,000 °C during the demonstration may have caused partial oxidation of petroleum hydrocarbons. Alternatively, the ketones may have been volatilized from groundwater. At this time, insufficient data are available to determine the source of ketones found in treated soils.

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IONICS/RESOURCES CONSERVATION COMPANY (B.E.S.T. Solvent Extraction Technology)

TECHNOLOGY DESCRIPTION:

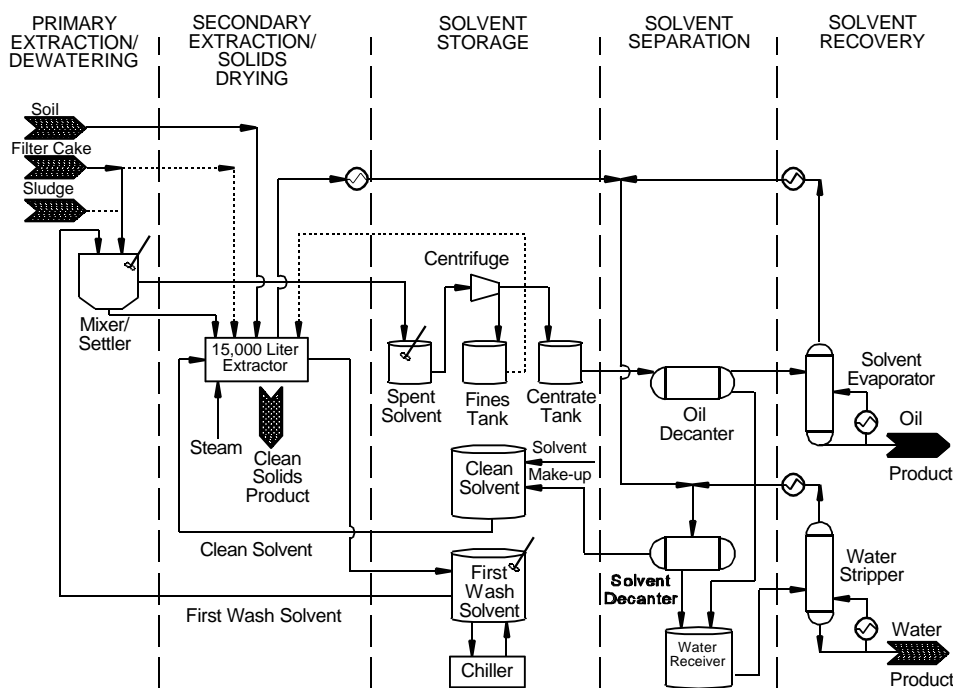
Solvent extraction treats sludges, sediments, and soils contaminated with a wide range of hazardous contaminants including polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons (PAH), pesticides, and herbicides. The waste matrix is separated into three fractions: oil, water, and solids. Organic contaminants, such as PCBs, are concentrated in the oil fraction, while metals are separated into the solids fraction. The volume and toxicity of the original waste is thereby reduced, and the concentrated waste streams can be efficiently treated for disposal.

The B.E.S.T. technology is a mobile solvent extraction system that uses secondary or tertiary amine solvents to separate organics from soils, sediments, and sludges. The B.E.S.T. solvents are hydrophobic above 20 °C and hydrophilic below 20 °C. This property allows the process to extract both aqueous and nonaqueous compounds by changing the solvent temperature.

Pretreatment includes screening the waste to remove particles larger than 1 inch in diameter, which are treated separately.

The B.E.S.T. process begins by mixing and agitating the solvent and waste in a mixer/settler. Solids from the mixer/settler are then transferred to the extractor/dryer vessel. (In most cases, waste materials may be added directly to the extractor/dryer and the mixer/settler is not required.) Hydrocarbons and water in the waste simultaneously solubilize with the solvent, creating a homogeneous mixture. As the solvent breaks the oil-water-solid emulsions in the waste, the solids are released and settle by gravity. The solvent mixture is decanted from the solids and centrifuged to remove fine particles.

The solvent-oil-water mixture is then heated. As the mixture's temperature increases, the water separates from the organics and solvent. The organics-solvent fraction is decanted and sent to a solvent evaporator, where the solvent is



B.E.S.T. Solvent Extraction Technology

recycled. The organics are discharged for recycling, disposal, or treatment. The water passes to a steam stripping column where residual solvent is recovered for recycling. The water is typically discharged to a local wastewater treatment plant.

The B.E.S.T. technology is modular, allowing for on-site treatment. The process significantly reduces the organic contamination concentration in the solids. B.E.S.T. also concentrates the contaminants into a smaller volume, allowing for efficient final treatment and disposal.

WASTE APPLICABILITY:

The B.E.S.T. technology can remove hydrocarbon contaminants such as PCBs, PAHs, pesticides, and herbicides from sediments, sludges, or soils. System performance can be influenced by the presence of detergents and emulsifiers.

STATUS:

The B.E.S.T. technology was accepted into the SITE Demonstration Program in 1987. The SITE demonstration was completed in July 1992 at the Grand Calumet River site in Gary, Indiana. The following reports are available from EPA:

- Applications Analysis Report (EPA/540/AR-92/079)
- Technology Evaluation Report - Volume I (EPA/540/R-92/079a)
- Technology Evaluation Report - Volume II, Part 1 (EPA/540/R-92/079b)
- Technology Evaluation Report - Volume II, Part 2 (EPA/540/R-92/079c)
- Technology Evaluation Report - Volume II, Part 3 (EPA/540/R-92/079d)
- Technology Demonstration Summary (EPA/540/SR-92/079)

The first full-scale B.E.S.T. unit was used at the General Refining Superfund site in Garden City, Georgia. A 75-ton-per-day B.E.S.T. unit is being installed at Idaho National Engineering Laboratory to extract organic contaminants from mixed wastes.

DEMONSTRATION RESULTS:

The SITE demonstration showed that the B.E.S.T. process removed greater than 99 percent of the PCBs found in river sediments without using mechanical dewatering equipment. Treated solids contained less than 2 milligrams per kilogram PCBs. Comparable removal efficiencies were noted for PAHs.

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KAI TECHNOLOGIES, INC./ BROWN AND ROOT ENVIRONMENTAL (Radio Frequency Heating)

TECHNOLOGY DESCRIPTION:

Radio frequency heating (RFH) is an in situ process that uses electromagnetic energy to heat soil and enhance soil vapor extraction (SVE). The patented RFH technique, developed by KAI Technologies, Inc. (KAI), uses an antenna-like applicator inserted in a single borehole to heat a volume of soil. Large volumes of soil can be treated by RFH employing a control system and an array of applicators. When energy is applied by the applicator to the soil, heating begins near the borehole and proceeds radially outward. This technique can achieve a soil temperature in excess of 250 °C.

RFH enhances SVE in two ways: (1) contaminant vapor pressures are increased by heating; and (2) soil permeability is increased by drying. Extracted vapor can then be treated by a variety of existing technologies.

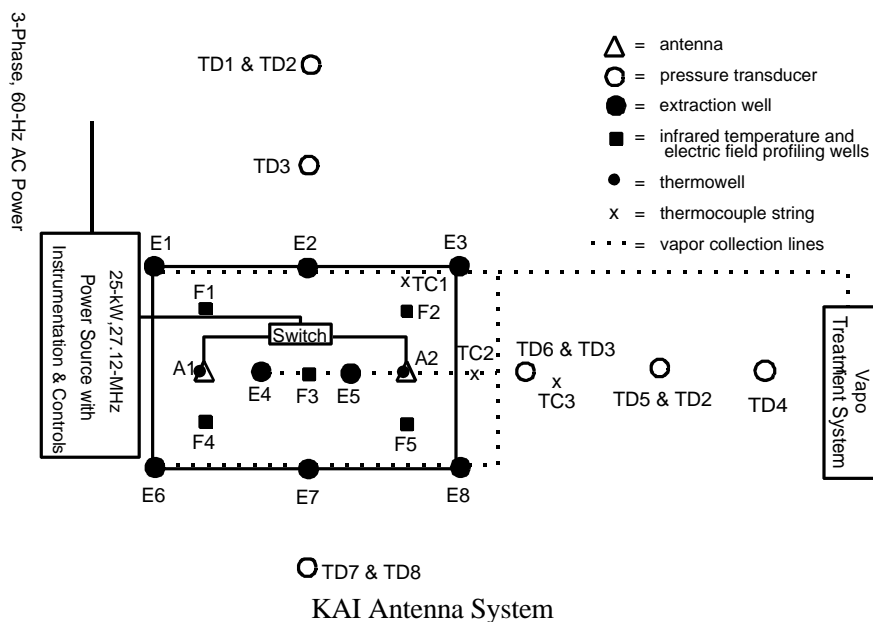
WASTE APPLICABILITY:

The RFH technique has been tested using pilot-scale vertical and horizontal antenna orientations to remove petroleum hydrocarbons and volatile and semivolatile organics from soils. The technology is most efficient in

subsurface areas with low groundwater recharge. In theory, the technology should be applicable to any polar compound in any nonmetallic medium. The flexible design permits easy access for in situ treatment of organics and pesticides under buildings or fuel storage tanks.

STATUS:

The KAI RFH technique was accepted into the SITE Demonstration Program in summer 1992. The technique was demonstrated between January and July 1994 at Kelly Air Force Base, Texas as part of a joint project with the U.S. Air Force Armstrong Laboratory. Brown and Root Environmental was the prime contractor evaluating and implementing RFH for the U.S. Air Force. A field demonstration of the IIT Research Institute RFH technology was completed in summer 1993 at the same site for comparison. The Demonstration Bulletin (EPA/540/MR-94/528), Technology Capsule (EPA/540/R-94/528a), and Innovative Technology Evaluation Report (EPA/540/R-94/528) are available from EPA. For further information on the IIT Research Institute technology, see the profile in the Demonstration Program section (completed projects).



DEMONSTRATION RESULTS:

For this demonstration, the original treatment zone was 10 feet wide, 15 feet long, and 20 feet deep. This treatment zone was based on RFH operation at 13.56 megahertz (MHz); however, RFH was applied at 27.12 MHz to the top 10 feet of the original treatment zone to reduce the time on site by half. Demonstration results were as follows:

- Uniform heating within the revised heating zone: significant regions had soil temperatures in excess of 100 °C with soil temperatures within a 3-foot radius of the antenna exceeding 120 °C.
- Significant amounts of liquid were heated to around 240 °C as strongly suggested by a measurement of 233.9 °C on the outside wall of the heating well liner.
- Soil permeability increased by a factor of 20 within the revised treatment zone.
- In the original treatment zone, the mean removal for total recoverable petroleum hydrocarbons (TRPH) was 30 percent at the 90 percent confidence level. Concentrations in the pretreatment samples varied from less than 169 to 105,000 parts per million (ppm); posttreatment concentrations varied from less than 33 to 69,200 ppm.
- In the revised treatment zone, the mean removal for TRPH was 49 percent at the 95 percent confidence level. Concentrations in the pretreatment samples varied from less than 169 ppm to 6,910 ppm; posttreatment concentrations varied from less than 33 ppm to 4,510 ppm.
- Benzo(o)fluoranthene, benzo(a)pyrene, and bis(2-ethylhexyl)phthalate exhibited statistically significant removals within the original treatment zone. Benzo(o)-fluoranthene, benzo(a)pyrene, chrysene, pyrene, and fluoranthene exhibited statistically significant removals within the revised treatment zone.

- Contaminants may have migrated into and out of the revised treatment zone due to the design and operation of the SVE system.
- Cleanup costs are estimated to range from less than \$100 per ton for large scale to between \$150 to \$250 per ton for small-scale (hot spot) treatments.

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MAGNUM WATER TECHNOLOGY (CAV-OX® Process)

TECHNOLOGY DESCRIPTION:

The CAV-OX® process uses a combination of hydrodynamic cavitation and ultraviolet (UV) radiation to oxidize contaminants in water. The process (see figure below) is designed to remove organic contaminants from wastewater and groundwater without releasing volatile organic compounds into the atmosphere.

The process generates free radicals to degrade organic contaminants. The cavitation process alone has been demonstrated to achieve trichloroethene (TCE) reductions of up to 65 percent. UV excitation and, where necessary, addition of hydrogen peroxide and metal catalysts, provide synergism to achieve overall reductions of over 99 percent. Neither the cavitation chamber nor the UV lamp or hydrogen peroxide reaction generates toxic by-products or air emissions.

Magnum Water Technology (Magnum) estimates the cost of using the CAV-OX® process to be about half the cost of other advanced UV oxidation systems and substantially less than carbon adsorption. Because the process equipment has one moving part, maintenance costs are minimal. According to Magnum, the CAV-OX® process does not exhibit the quartz tube scaling common with other UV equipment.

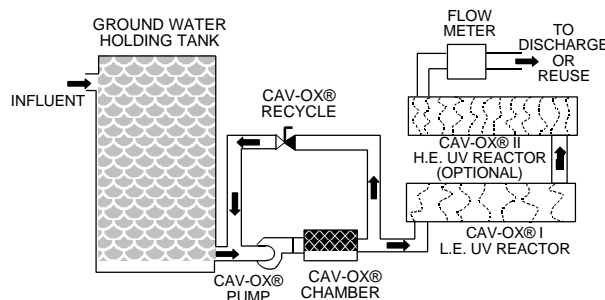
The process is designed to treat groundwater or wastewater contaminated with organic compounds. Contaminants such as halogenated solvents; phenol; pentachlorophenol (PCP); pesticides; polychlorinated biphenyls; explosives; benzene, toluene, ethylbenzene, and xylenes; methyl tertiary butyl ether; other organic compounds; and cyanide are suitable for this treatment process. Bacteria and virus strains are also eliminated.

STATUS:

This technology was accepted into the SITE Demonstration Program in summer 1992 and was demonstrated for 4 weeks in March 1993 at Edwards Air Force Base (AFB) Site 16 in California. The Applications Analysis Report (EPA/540/AR-93/520), Technology Evaluation Report (EPA/540/R-93/520), and a videotape are available from EPA.

Magnum reports that improvements in UV lamp and reactor technologies have improved the efficiency of the CAV-OX® process three- to five-fold, compared with the pilot-scale unit tested at Edwards AFB under the SITE Program.

WASTE APPLICABILITY:



The CAV-OX® Process

CAV-OX® recently (1996) has proven very effective in potentiating ozone concentrations in water reclamation applications. Ozone gas (O₃) is relatively insoluble in water. However, hydrodynamic cavitation used in the CAV-OX® process continuously develops micro bubbles which enhances the dispersion of ozone in water. Three O₃ techniques are available to Magnum: corona discharge with air feed, electrochemical 'water splitting' method, and electrochemical anodic oxidation.

The CAV-OX® process has been tested at several public and private sites. At a Superfund site, the process treated leachate containing 15 different contaminants. PCP, one of the major contaminants, was reduced by 96 percent in one test series. The process has also been used to remediate former gasoline station sites and successfully reduced contaminants in process streams at chemical and pharmaceutical plants.

The CAV-OX® unit is part of an ongoing evaluation at the U.S. Army Aberdeen Proving Ground. Features of the unit to be tested include remote monitoring and control systems for pH; flow; H₂O₂ flow rate, storage level, and pump rate; UV lamp, main power, and CAV-OX® pump function; and system shutdown control.

DEMONSTRATION RESULTS:

The CAV-OX® process achieved removal efficiencies of greater than 99.9 percent for TCE, benzene, toluene, ethylbenzene, and xylenes. SITE demonstration results for the CAV-OX® process are shown in the table below. Results are presented for both the CAV-OX® I (cavitation chamber by itself) and CAV-OX® II (cavitation chamber combined with ultraviolet radiation) demonstrations.

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H ₂ O ₂ ¹ Concentrations (mg/L) ²	Flow (gpm) ³	TCE	CAV-OX® I Removal Efficiencies (%)			Flow (gpm)	TCE		CAV-OX® II Removal Efficiencies (%)					
			Benzene	Toluene	Xylene		5-kW ⁴	10-kW	Benzene 5-kW	Toluene 10-kW	Xylene 5-kW	Xylene 10-kW		
33.1	0.5	99.9	>99.9	99.4	92.9	1.5	99.6	99.2	99.4	98.8	>99.9	98.6	>99.9	>99.9
23.4	0.6	99.9	>99.9	>99.9	>99.9	2.0	99.7	99.7	99.5	99.6	>99.9	>99.9	>99.9	>99.9
4.9	1.5	71.4	88.6	87.4	65.6	4.0	87.7	98.1	89.7	98.7	88.8	97.1	78.7	87.2
48.3	0.6	99.7	>99.9	>99.9	>99.9	1.4	99.8	99.7	99.8	99.8	>99.9	>99.9	98.7	>99.9
6.0	0.7	87.8	96.9	94.5	92.1	1.9	98.4	99.3	98.8	99.3	96.9	98.6	93.6	97.0
4.9	1.5	61.7	81.6	83.8	80.2	3.9	85.1	97.1	89.5	97.8	91.8	97.9	90.4	96.0
5.9	0.5	96.4	99.4	99.8	98.9	1.4	99.6	99.4	99.6	99.6	99.8	99.8	99.5	99.5
5.9	0.7	87.1	96.5	97.6	98.1	1.9	97.8	99.2	99.4	99.5	99.5	99.7	99.2	99.7
6.1	1.5	60.6	86.1	87.3	>99.9	4.0	86.3	98.9	93.5	99.5	94.5	99.6	95.4	>99.9
0	-	-	-	-	-	1.6	94.1	99.2	49.1	68.1	20.7	54.7	43.3	46.7
0	-	-	-	-	-	1.8	80.6	97.6	38.5	60.5	48.6	75.2	56.9	83.8

¹ hydrogen peroxide ² milligrams per liter ³ gallons per minute ⁴ kilowatts

CAV-OX® Process Demonstration Results